

New Scientist

WEEKLY November 22-28, 2014

SPECIAL REPORT

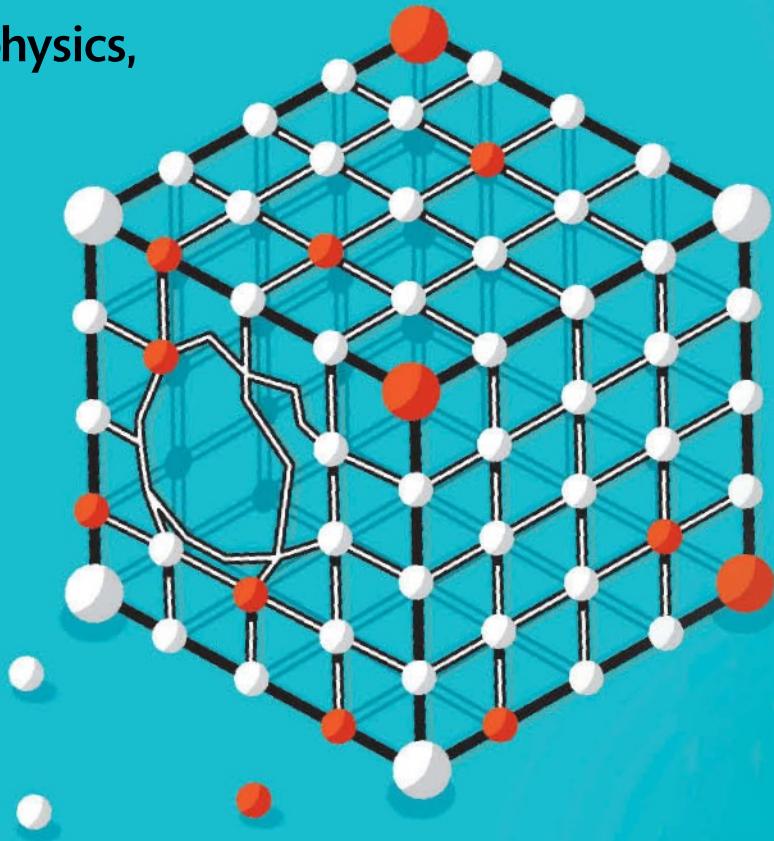
WHAT NEXT FOR PHILAE?

The comet mission has only just begun



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CONTENTS

News

8

What next for Philae?

The comet mission has only just begun



On the cover

36

Outsmarting reality

You can't break the laws of physics, but you can bend them

Cover image

Harry Campbell

8 What next for Philae?

Comet mission has only just begun

40 Listen to yourself

How the noises you make influence how you feel

44 Bunny boiler

Snowshoe hares in a warming world

46 Dam problem

Big trouble at the Three Gorges



Features

44

Bunny boiler

Warming world makes snowshoe hares easy prey

NORBERT ROSCH/NATIONAL GEOGRAPHIC/CREATIVE



Coming next week...

Toxic shockers

How dangerous are everyday chemicals?

Ancestors unearthed

The greatest ever find of early human remains

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Volume 224 No 2996

This issue online
newscientist.com/issue/2996

News

6 UPFRONT

Bird flu threat to Christmas turkeys. Ebola drug trials start. Russia's secret rocket

8 THIS WEEK

Huge study homes in on "gay genes". The evolution of weeds. Earth's backup plan: cache human DNA on the moon. Teach yourself synaesthesia

16 INSIGHT

Climate pledges aren't enough - but there is a solution

19 IN BRIEF

How to build habitable exomoons. 3D-printed contact lenses. Starfish killer identified

Technology

23 Hackers take on Ebola. Home alarm listens in for break-ins. Tiger detector keeps everyone safe. Donate direct to those in need

Aperture

28 Meet the most decorated animal in the sea

Opinion

30 Tragedy of the commons Petros Sekeris on how we risk repeating Easter Island's mistakes

31 One minute with... Josh Tetrick The secret ingredient in my planet-friendly products

32 Get it right John Ioannidis challenged science's flaws - and now gets rid of them

34 LETTERS Quantum computers. Talking TTIP

Features

36 Outsmarting reality (see above left)

40 Listen to yourself How the noises you make influence the way you feel

44 Bunny boiler (see left)

46 Dam problem Big trouble at the Three Gorges

CultureLab's gift guide

50 Be inspired! Seasonal whimsy, from mouse taxidermy to chocolate body parts

52 Cracking reads Treat friends and family to a science page-turner this Christmas

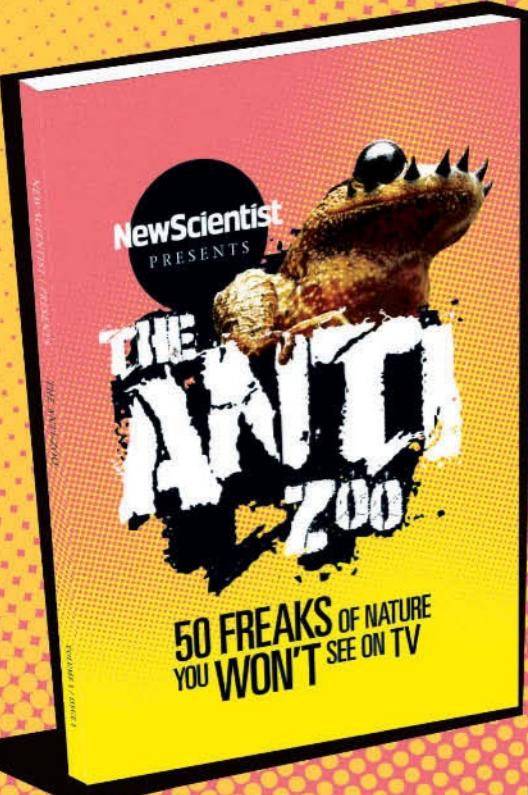
Regulars

5 LEADER Discovering the genetic basis of homosexuality is a double-edged sword

56 FEEDBACK Silence and gold

57 THE LAST WORD Boil foils

54 JOBS & CAREERS



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Can alligators use tools?
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JONATHAN ERNST/REUTERS

Get over it

Genetic or not, homosexuality is innately human

FOR gay rights activists, it's a dilemma. Does it help or hinder their cause if science shows that homosexuality is partly or largely biologically determined, rather than a lifestyle choice?

On the one hand, if sexual orientation is something people are born with, and cannot change even if they want to – akin to skin colour or handedness – this should overturn the notion that people choose to be gay and could equally well choose not to be. That knowledge would help rebut those who suggest that gayness is the result of a morally unacceptable decision, or a psychological disorder. It might also help people who struggle to understand or declare their own homosexuality.

On the other, some could try to redefine homosexuality as a biological abnormality. There is no way to change people's sexuality, but if key genes are found, it might be possible to detect homosexuality before birth, or to "cure" people by altering those genes. Even the threat of this could be used to persecute: consider the ugly histories of prenatal sex selection and of coerced and ineffectual "therapies" for homosexuals. It is no wonder that some activists see in such research the "seeds of genocide".

This debate has rumbled on for

years. But as we report this week, there is growing evidence that male homosexuality has a strong genetic contribution (see page 11). Other biological components of homosexual behaviour have also been found: brain structures that differ with sexual orientation, for example, and robust theories for how genes survive in the population despite rarely being passed on by homosexual people.

To socially liberal and tolerant

**"You might as well ask:
why not search for genes
that make some people
virulently homophobic?"**

people, this new knowledge will be entirely unchallenging. It is in circles where homosexuality is still considered problematic – of which there are many – that it could have implications.

There is some evidence that people who see homosexuality as biologically determined are more tolerant than those who see it as a lifestyle choice. But it is not clear which way the arrow of causation points: it may be that tolerant people are more inclined to believe in biological determinism. And there is also a growing understanding that simply presenting people with evidence that contradicts their

world views does not change their minds: rather than assimilate the information, they just intensify their efforts to reject it.

This seems a likely response among those who object to homosexuality. Homophobia has deep and complex causes. It may itself be partly biological in origin: for example, straight people with a stronger innate disgust response are also more likely to oppose gay marriage. You might as well ask: why not search for genes that make some people virulently homophobic?

Science cannot overturn such prejudice on its own, particularly when it clashes with world views that stipulate how society should be ordered. From these spring the urge to show that homosexuality is "unnatural", which the genetic evidence disputes. But human sexuality is in any case flexible and creative. Deeming certain behaviours unnatural is absurd: most of us have desires that could be labelled thus, and the natural world abounds with practices no human would attempt.

Ultimately, what causes homosexuality doesn't matter as much as the fact that homosexual people exist, and have always existed, in every society on earth. In the words of the activists: some people are gay. Get over it. ■

Bird flu threat to turkeys

BAD news for Christmas dinner. A strain of bird flu has hit a duck farm in Yorkshire, a region where many of the UK's turkeys are farmed. The festive birds are the most vulnerable poultry species, and infection can kill them.

The virus is likely to be the H5N8 strain that struck turkeys earlier this month in Germany and chickens in the Netherlands. The entire flock of more than 30,000 turkeys on the German farm have been destroyed.

The virus can be traced back to South Korea. It appeared in poultry farms there in January and has since been spotted in wild birds and poultry in Japan and China. It is a hybrid of H5N1, the strain that has killed hundreds of people since it left China in 2003, and two other viruses. It probably came to Europe

with migrant ducks that had nested alongside Korean birds.

The hybrid has three genes from H5N1, including some mutations thought to help it infect mammals. There are no known cases of people catching H5N8, but after the outbreak in Germany Thomas Mettenleiter of that nation's Federal Research Institute for Animal Health, said: "We have to assume that every highly pathogenic virus can also represent a danger to humans."

H5N8 also carries a mutation that makes it much deadlier to chickens and turkeys than most bird flu carried by wildfowl. Poultry farms try to exclude wild birds, but turkeys are so sensitive that merely walking in droppings of infected birds then entering a turkey barn can spread it.



If Christmas doesn't get you...

Ebola drug trials

DRUGS for Ebola are finally getting closer. Two antiviral drugs will be tested in West Africa – without placebo control – starting next month. According to Médecins sans Frontières, trials will involve simply giving a drug to between 100 and 200 people, then monitoring their progress over the following two weeks.

The University of Oxford is running one trial investigating brincidofovir, an antiviral owned by US firm Chimerix. Inserm, the French national institute

ethical nor practical for Ebola. The trial will be more like a triage, he says, allowing investigators to decide which drugs clearly work and which don't. If death rates remain above 50 per cent, the trial will be halted. If survival at two weeks is above 80 per cent, the trial will also be stopped – but switched to larger-scale trials. Anything in between, he says, will require more careful testing. "I would rather do a trial that I know can deliver a clear result," he says.

In another trial, Johan van Griensven of the Antwerp Institute of Tropical Medicine in Belgium will test whether blood transfusions from Ebola survivors boost 100 people's odds of survival.

It has taken several months to settle all the legal issues and decide on the experimental design. Getting approval from regulators in the countries affected and those running the trials is ongoing. The blood and favipiravir trials will take place in Guinea. The site of the brincidofovir trial has not yet been decided.

Results are expected by March, or earlier if effects are good.

"The trial will be more like a triage, to decide which drugs clearly work and which don't"

for medical research, is running the other. Led by Denis Morvay of the University of Bordeaux, it will trial an anti-flu drug called favipiravir shown to cure Ebola in monkeys and owned by Fujifilm of Japan.

Peter Horby, who heads the Oxford team, says that placebo-controlled trials are neither

Park concern

QUANTITY or quality? When it comes to protected areas, the emphasis is still on the former. But is this best?

Since the World Parks Congress in Durban, South Africa, in 2003, the number of protected areas around the world has doubled. We are on track to achieve the target of protecting 17 per cent of Earth's land and 10 per cent of the oceans by 2020.

But the Protected Planet Report 2014, released at the World Parks

Congress in Sydney, Australia, last week, revealed not enough was being done to ensure areas were selected for their biodiversity. Depressingly, the same message emerged from the 2003 meeting.

The report also found park management was being checked in only a third of the areas and, of these, three quarters did not have sound management. "We need more research and action on the ground to ensure protected areas deliver benefits to all," says Naomi Kingston, a lead author of the report.

Tuna boom and bust

IT'S a tale of two tunas. Nations have agreed to increase Eastern Atlantic bluefin tuna fishing quotas, just as the threat status of the Pacific bluefin tuna has been upgraded on the Red List of threatened, endangered and extinct species.

Pacific bluefin tuna was previously of "least concern", but its popularity in sushi and sashimi has caused the population to decline by almost a third in the last 22 years, and it is now classified as "vulnerable".

"The growing food market is putting unsustainable pressure on... species," said Jane Smart of the International Union for Conservation of Nature in a statement.

Meanwhile, the International Commission for the Conservation of Atlantic Tunas agreed on Monday to allow Atlantic bluefin tuna fishing quotas to grow by 20 per cent annually over the next three years. This follows recent improvements in Atlantic bluefin tuna stocks.

60 SECONDS

Mystery satellite

IS IT watching the watchers? Russia has launched a spacecraft that is whizzing around low Earth orbit visiting satellites, it emerged this week. The mystery craft has renewed fears that

"Kosmos 2499 is making regular changes to its orbit, and has visited the rocket that launched it"

Russia has revived its interest in developing anti-satellite weapons, a programme thought to have been abandoned in the 1980s.

Kosmos 2499 was launched from the Plesetsk Cosmodrome in northern Russia on 23 May alongside three communications satellites. US Air Force Space Command is believed to be monitoring it closely.

Its three companions – Kosmos 2496, 2497 and 2498 – are thought to be for military communications, says David Todd, an analyst with space-flight data provider Seradata of Welford, UK. "The fourth spacecraft, Kosmos 2499, is making regular changes to its orbit, including making a visit on 28 October to the Briz-M rocket stage that launched it," he says.

Todd thinks there might be a more prosaic explanation. Other nations, including the US, send spacecraft to inspect problem satellites. Kosmos 2499 might just be doing the same, he says.

INSIVAS/REUTERS/CORBIS



Vulnerable to cold

Preterm deaths

THE tide is turning on child mortality. For the first time, an infectious disease isn't the leading killer of infants around the world. That position has been taken by complications resulting from premature birth.

While deaths from infectious diseases are declining as a result of research and medical intervention, preterm birth has remained a difficult problem, says Joy Lawn at the London School of

"Simple measures like improved feeding and antibiotics could improve survival rates"

Hygiene and Tropical Medicine.

She and her colleagues have studied child mortality rates and their causes between 2000 and 2013. Of the 6.3 million children worldwide who died before the age of 5 last year, 1.1 million died from complications associated with being born at less than 32 weeks. This was more than those who lost their lives to any single infectious disease. Taken together, the number of deaths from all infections is higher than the number of neonatal problems, but only by 6 per cent. Those figures were highest in India, Nigeria, Pakistan, the Democratic Republic of the Congo and

China (*The Lancet*, doi.org/w7d).

In low-income countries, basic treatments can have a big impact, says Lawn. "Simple measures like improved feeding and antibiotics could go a long way".

In developed nations, doctors are trying to prevent babies being born early. Contributing factors include women giving birth later in life, obesity and smoking.

Enriching Iran

IRAN may be on the brink of a historic deal. The country is entering the final stage of nuclear negotiations with the US and five other countries.

In 2002, Iran began escalating its uranium enrichment efforts, a necessary process for operating nuclear power plants, but also a step towards the production of nuclear warheads. Since then, sanctions and talks – between Iran, the US, the UK, France, Germany, Russia and China – have built to a 24 November deadline set last year for a long-term agreement on what Iran will be able to do.

The US wants Iran to agree to a reduced capacity of enriching centrifuges, but Iran doesn't want to do this, and wants reassurance that it will be able to continue with its plans for nuclear power. Analysts suggest that sanctions against Iran will have to be lifted if a deal is to be struck.



Plenty more fish in the sea?

NEIL LUCAS/NATUREPL.COM

Kamikaze bees

You're a bee without a sting and your home is under attack. How can you drive off the enemy? Bite, and never let go. More than 80 per cent of *Trigona hyalinata* bees from Brazil will keep biting an intruder even at the risk of certain death (*Behavioral Ecology and Sociobiology*, doi.org/w64).

Intimate exchange

A kiss is not just a kiss – it's also an exchange of 80 million bacteria. That number was worked out by getting 21 couples to try a bacteria-laden yogurt drink and then kiss for 10 seconds. Couples who enjoy at least nine "intimate kisses" a day are also more likely to have similar communities of bacteria in their mouths (*Microbiome*, doi.org/w7g).

Harlem globe surfers

The Big Apple is about to get wired, wirelessly. New York City plans to install 10,000 Wi-Fi kiosks that will provide free, high-speed broadband. The LinkNYC project, which will replace old payphones, will also provide free phone calls and cellphone charging stations. The first kiosks will be built in late 2015.

Yum, tag-liatelle

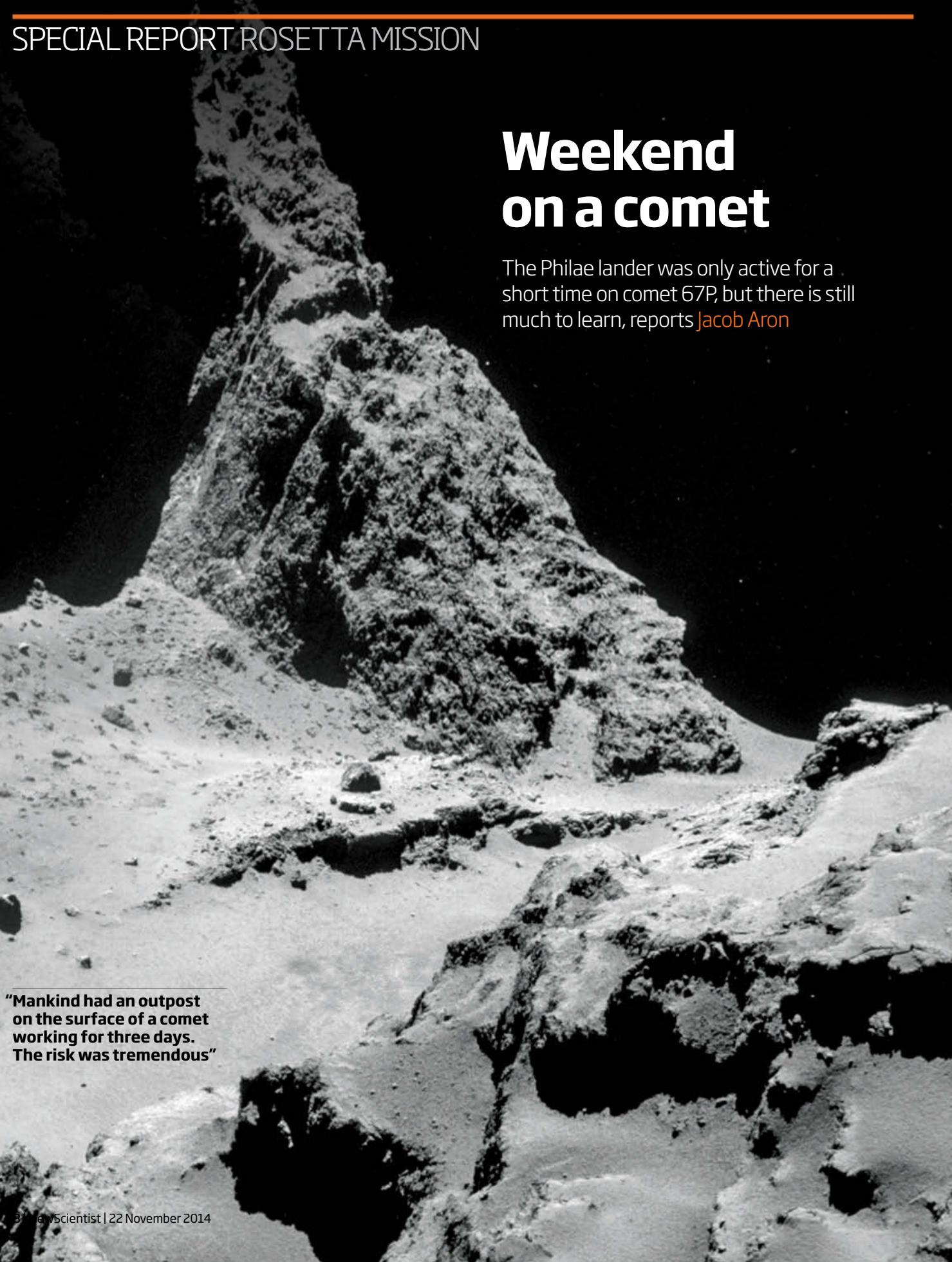
It's been dubbed the "dinner bell" effect. Captive grey seals learn to locate hidden food 30 times faster if their fish prey carry a tracking tag that emits sounds. That could be bad news for fish being tracked in the wild – they may become easy meat for predators (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2014.1595).

Controversy in store

Westminster, Massachusetts, could become the first town in the US to ban all shops from selling any tobacco or products that contain nicotine. But smokers and non-smokers have joined forces to sign a petition against the plan, on the grounds that it undermines personal liberties.

Weekend on a comet

The Philae lander was only active for a short time on comet 67P, but there is still much to learn, reports **Jacob Aron**



"Mankind had an outpost on the surface of a comet working for three days. The risk was tremendous"

In this section

- Huge study homes in on "gay genes", page 11
- Teach yourself synesthesia, page 16
- Home alarm listens in for break-ins, page 24

LANDING on a comet was never going to be easy. Last week, the European Space Agency's Philae spacecraft, the first robotic probe designed to grapple and drill a comet, bounced and skidded its way across the alien surface before settling in for what might be a long nap. The excitement of the landing may be dying down, but researchers are just beginning to take stock of events - and Rosetta, Philae's mother ship, might even get its own chance to touch the comet.

"Mankind had an outpost on the surface of a comet working for three days," says Rosetta flight director Andrea Accomazzo. "A few things didn't work exactly as we wished, but we knew that the risk was tremendous."

Rosetta spent a decade flying to comet 67P/Churyumov-Gerasimenko, and spent three months mapping its surface to prepare for Philae's touchdown.

That historic landing happened on 12 November, as the world watched.



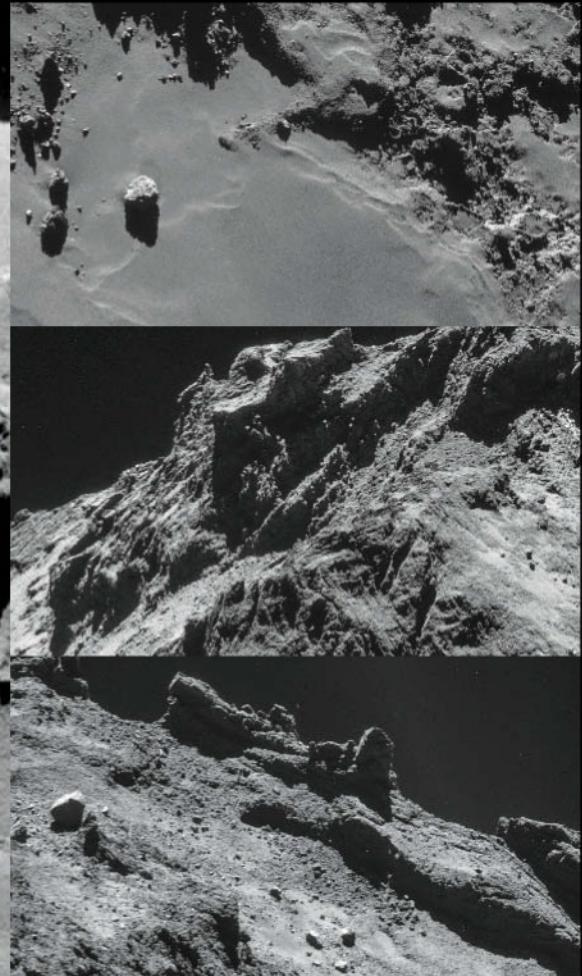
"We are there and Philae is talking to us," said lander manager Stephan Ulamec from the European Space Operations Centre in Darmstadt, Germany. "We are on the comet!"

But the landing didn't go as planned. The three systems designed to attach Philae to the surface - a gas thruster, harpoons and ice screws - all failed, so the spacecraft bounced twice before coming to a halt, angled against a shadowed cliff with one leg in the air. Without enough sunlight to recharge its batteries, Philae went into a deep sleep. There is a chance it could revive as the comet moves closer to the sun, but for now researchers are busy dissecting the wealth of data Philae managed to upload before it shut down.

Rosetta and Philae were charged with discovering whether life on Earth was kick-started by comets. These icy space rocks are leftover material from the cloud of dust and gas that formed our solar system 4.6 billion years ago, so investigating them gives us a peek at the pristine building blocks of planets. What's more, comets may have rained down on Earth after it formed, providing water and other molecules necessary for life.

Despite its brief time on the surface, all 10 of Philae's instruments took readings in an attempt to tackle this question, although it is still unclear whether the botched landing means some failed to gather meaningful data. The lander's two sets of cameras returned dramatic pictures of its descent and landing, which will help uncover the comet's composition. CONSERT, a radar system shared by Philae and Rosetta, probed the internal structure of the comet, and was also jury-rigged to help track Philae as it bounced across the surface.

The lander wasn't able to run ➤



ESAROSETTA NAVCAM TOP:ESA/ATGMEDIALAB

WHAT THEY SAID

"It's worked, it's landed, it's landed! I've waited years for this and I'm just so excited! Sorry, now I'll try and be a professional scientist"

Monica Grady, Philae team member, moments after the probe landed

"In the same way the Rosetta Stone unlocked language so the @ESA_Rosetta mission may unlock more secrets of the universe"

William Shatner, actor, *Star Trek*

"It may seem like a work of fiction, but it is very real, very impressive, and will help us to further uncover the mysteries surrounding the formation of our solar system"

Stephen Hawking, theoretical physicist

"I would like to congratulate all the team who made this successful landing. They made the miracle possible"

Klim Churyumov, co-discoverer of comet 67P

"My #lifeonacomet has just begun @ESA_Rosetta. I'll tell you more about my new home, comet #67P SOON...zzzzz"

Final tweet from @Philae2014, the lander's official twitter account

"@Philae2014 You've done a great job Philae, something no spacecraft has ever done before. #CometLanding"

Farewell tweet from @ESA_Rosetta, the orbiter's official twitter account

SPECIAL REPORT ROSETTA MISSION

through a preprogrammed sequence of investigations, so the team had to choose which instruments to activate first. Any with moving parts could have jolted the spacecraft, jeopardising its tenuous hold on the comet.

Desperate hammer

A suite of instruments called MUPUS that included a probe and hammer was one of the first activated. It took the comet's temperature at a frigid -153 °C, but had trouble with the hammer. The team ramped through three modes to a fourth "desperate mode", which broke the hammer after 7 minutes, without cracking the surface. The team says that under 10 to 20 centimetres of dust, the comet is as hard as ice, which could explain why Philae bounced.

The final and most risky operation was switching on Philae's drill. The drill was supposed to dig 25 centimetres into the surface and return samples to two other instruments: COSAC, which analyses organic molecules to determine their shapes, and Ptolemy, which investigates molecular isotopes. Since ESA didn't know exactly how Philae



ESA/ROSETTA/PHILAE/CIVA

Hanging on for dear life

was positioned, it wasn't clear if the drill could actually reach the surface. And with battery running out, there was only time to extract a single sample – one instrument would have to go without.

In the end ESA decided to give the sample to COSAC, which can identify whether organic molecules are left or right-handed. Both types are produced in equal amounts through chemical processes, but for some unknown reason, life on Earth

contains only left-handed molecules. A particular chemical reaction on comets could be responsible for the imbalance. Researchers are still working to confirm whether the drill did indeed extract a sample, although ESA says COSAC has identified organic molecules in the gas around the comet.

Ian Wright, who is in charge of Ptolemy, says some surface material entered that instrument's sensors during the bounce. "We did a scratch and sniff," he says. "We've got measurements from two different places on the surface."

Rosetta mission manager Fred Jansen says the landing was

"I'm very confident Philae will resume contact with us and that we will be able to operate the instruments"

always given only a 75 per cent chance of working. "We always knew we could end up on a slope and then the drill wouldn't work," he says, though he concedes potentially losing the chance to sample beneath the comet's surface will be a blow. On the flip side, landing in two places has let them study multiple points on

the comet. "For me this is an absolute success on such a daring enterprise."

As *New Scientist* went to press, ESA was still trying to identify Philae's final resting place. Pinpointing its landing spot should help calculate when the craft is most likely to be revived.

Accomazzo thinks the odds are low, "more than 1 per cent and less than 50". But Ulamec is more optimistic. "I'm very confident that Philae will resume contact with us and that we will be able to operate the instruments again," possibly in the spring or summer of 2015, he said.

Rosetta itself could one day join Philae on comet 67P. The orbiter will run out of fuel at the end of 2016, and ESA must decide whether to put it into hibernation, or put it down on the surface. A large flat area on the dark side of the comet was not an option for Philae, but it will be well illuminated by 2016. Rosetta could crash-land there, taking extreme close-up pictures of the comet and sniff its atmosphere on the way down. "If we are called to do something like this I would be pleased," says Accomazzo. "If you ask me personally, I wouldn't do anything else." ■

DATES FOR YOUR SPACE DIARY

Has the excitement of Philae's landing got you fired up for the next space mission? Here are our highlights of what the world's space agencies have in store:

2014: At the end of November, Japan's space agency JAXA is to launch Hayabusa 2, a sequel to the first soft landing on an asteroid. When the craft reaches its target asteroid, 1999 JU3, in 2020, it will release a lander called MASCOT, a cousin to Philae and built by the same team.

2015: In July, NASA's New Horizons spacecraft will fly past Pluto, giving us a close look at this distant dwarf planet. If you can't wait, in February

the probe should beam back pictures with a resolution that beats that of the Hubble Space Telescope.

2016: In March, NASA will launch its next mission to Mars, a lander called InSight, designed to investigate the planet's interior.

2018: ESA and Russia are teaming up to launch ExoMars, a rover that will land on Mars and explore the planet's surface for signs of life.

2022: Jupiter Icy Moon Explorer, an ESA mission affectionately known as JUICE, will launch to explore Jupiter in the 2030s. It will investigate the potential for liquid water and life on the moons Ganymede, Callisto and Europa.

Best brotherly clue yet to gay genetics

Andy Coghlan

MANY gay people say they have always known they were different. Now we have taken a step towards understanding why. A major study of gay brothers has yielded the best evidence yet that gay people are born that way. It links sexual orientation in men with two regions of the genome highlighted by previous studies – suggesting that being gay is biologically determined.

"It erodes the notion that sexual orientation is a choice," says study leader Alan Sanders of the NorthShore Research Institute in Evanston, Illinois. The finding has wider implications for society, given that being gay is criminalised in countries such as Uganda, and that some religious groups believe that gay people can be "treated" to make them straight.

The study picked out a region on the X chromosome called

Xq28. It was originally identified in 1993, but attempts to validate the finding have been mixed. The other region highlighted lies within the twist in the centre of chromosome 8. Known as 8q12, it was first implicated in 2005.

Sanders's study involves about three times as many men as the previous largest, which means it is more statistically robust. Over the past five years, his team has collected blood and saliva samples from 409 pairs of gay brothers, including some non-identical twins (see "Why I signed up", right, for one participant's thoughts). Only 40 pairs of brothers took part in the 1993 study.

The team combed through the samples, looking at the locations of genetic markers called single nucleotide polymorphisms (SNPs) – differences of a single letter in the DNA – and measuring the extent to which each of the SNPs were shared by the men.

The only trait common to all was being gay. Other traits, such as hair colour or intelligence, varied by different degrees between the brothers in a pair and between pairs. Therefore, any SNPs consistently found in the same genetic locations across the group would most likely be linked with sexual orientation.

Only five SNPs stood out and of these, the most likely to be shared were in the Xq28 and 8q12 regions (*Psychological Medicine*, doi.org/w65). But this doesn't mean the study found two "gay genes". Both regions contain many genes, and the next step will be to home in on which ones might be contributing to sexual orientation.

Sanders stresses that complex traits like sexuality depend on multiple factors, both genetic and

"Being straight, bi or gay is a central part of who we are, thanks in part to the DNA we were born with"

environmental. Even if we manage to hit on individual genes, they will likely have a small effect on their own, as studies of the genetic basis for intelligence have found.

Other researchers welcomed the findings, saying they resolve contradictory results from the earlier studies. It is pleasing that confirmation comes from a team that had been somewhat sceptical of previous findings, says Andrea Camperio Ciani of the University of Padua in Italy.

"Yes, we have a choice in life, to be ourselves or to conform to someone else's idea of normality. But being straight, bisexual or gay, or none of these, is a central part of who we are, thanks in part to the DNA we were born with," says neuroscientist Simon LeVay. In 1991, he claimed to have found that a part of the hypothalamus, within the brain, was smaller in gay men. "Much hard work now lies ahead to identify the specific genes involved and how they work, as well as to find equivalent genes in women," he says. ■



Not against nature, but with it

WHY I SIGNED UP

As a doctor, I recognise the importance of furthering science through legitimate research. As a gay man, I've known that my sexuality has never been a choice but I could not explain, to myself or anyone else, how I became this way. Genetics and environmental influences seemed logical. This study, which my twin brother and I took part in, is an attempt to answer the genetics part of the question.

The results may provide validation for homosexual men who have asked the same questions that I have. They may improve the self-esteem of those who have asked "why me?" or have felt ostracised, demonised, or worse. They may even change the minds of those who believe homosexuality is a "choice" rather than predetermined.

However, it is important that the findings be put in context. Inevitable headlines like "Gay gene discovered" or "It's not a choice" over-egg the results. Just because there is a genetic link to homosexuality, it does not guarantee one will end up gay. The genes, if and when they are found, may only predispose one to that possibility. Environmental, nutritional or other unknown factors may also need to be present at critical stages of development.

On a darker level, some may use the results to justify a belief that homosexuality is the result of a "broken" or "deviant" gene that needs to be fixed. Imagine parents requesting a genetic test on their unborn fetus, or worse, a government rolling out mandatory testing of all unborn children, and using abortions to "cleanse" the gene pool. There is enough hate in the world that this scenario is not as outrageous as one might think.

Although some countries are going backwards, there is a greater openness around the world to homosexuality. This, coupled with scientific evidence, will bring a greater understanding of human sexuality to a new generation. Chad Zawitz

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GETTY IMAGES

Weeds evolved fast on first farms

Colin Barras

IT DIDN'T take long. Just a few thousand years after humans began to domesticate crops, a wide variety of weeds had adapted to exploit the new farmlands – with some species seeming to have evolved, like crops, to be completely dependent on cultivated land.

Given the chance, weeds will take root in most agricultural settings. Today their presence lowers crop yields by 10 per cent globally, causing losses of tens of billions of dollars in profits each year.

But weed woes are nothing new. Ehud Weiss at Bar-Ilan University in Ramat-Gan, Israel, and his colleagues studied ancient seeds, fruits and other plant remains recovered from Atlit-Yam, a 9000-year-old coastal settlement now submerged a few metres below the Mediterranean Sea off the coast of Israel. The material

was waterlogged by seawater, meaning it was extremely well preserved.

The remains, which date to a time just 2000 years after farmers sowed their first seeds, include durum wheat, figs, chickpeas (garbanzos) and herbs. Alongside these important crops there is evidence of at least 35 weed species – suggesting that it didn't take long for opportunistic herbaceous plants to adapt to our agricultural revolution.

What's more, five of those species – including dandelion and Egyptian haworthia – appear to have been obligatory weeds, meaning they can usually only grow in cultivated fields.

They provide the earliest evidence yet that some weeds – as well as crops – adapted to agricultural settings within just a few millennia of the agricultural revolution (*Vegetation History and Archaeobotany*, doi.org/w5n).

George Willcox of the Lumière

University Lyon 2 in France describes the findings as a useful and important contribution to the study of the origin of agriculture, and the origin of weeds. Most of what we know about early agriculture comes from the charred remains of cooked plants. So finding plants from the dawn of agriculture that were exquisitely preserved in water is exciting, allowing researchers to accurately identify all the species. "Species-level identification allows the authors to assert with

"Weeds were found in plant remains from a time just 2000 years after farmers sowed their first seeds"

confidence that obligatory weeds were present," says Willcox.

What is a weed today may have had some uses yesterday, warns Simone Riehl at the University of Tübingen in Germany.

"Unfortunately, I can't interview the settlers of Atlit-Yam," says Weiss. But he adds that if a modern weed species' nutritional benefits hasn't improved much through the ages, it suggests it was probably a weed in the past too.

Is it possible that such useless, unwanted plants could have adapted so completely in just a few thousand years? Absolutely, says Kenneth Olsen at Washington University in St Louis, Missouri, who studies weeds as examples of fast adaptive evolution. "The development of agriculture would have opened up a new niche, and species that were already adapted to naturally disturbed habitats would be well positioned to rapidly spread to agricultural habitats," he says.

After this initial period of colonisation, weeds would have continued to adapt to the peculiar conditions found in agricultural settings, says Ana Caicedo at the University of Massachusetts Amherst. For instance, down the millennia some obligatory weeds have evolved to mimic the appearance of crop plants, allowing them to evade detection and removal by farmers. Remarkably, even this stage of weed adaptation might have been under way 9000 years ago at Atlit-Yam: dandelion is sometimes referred to as "false wheat" because of its resemblance to the crop.

Whether weeds would have been as problematic for early farmers as they are today is less clear. Bruce McDonald at the Swiss Federal Institute of Technology in Zurich thinks that the earliest farmers probably planted fields of mixed crops rather than monocultures, so even if a weed like dandelion brought down wheat yields, there should still have been a good harvest from other crops.

Monocultures might have come later, but there is evidence that they are relatively ancient. References to monocultures in the Old Testament suggest that farmers living a few millennia after Atlit-Yam was abandoned may have planted them.

"I'll bet that weeds were the big problem in early monocultures – and picking weeds may have consumed a lot of time for those early farmers," says McDonald. ■

Hair-raising moon shot to cache your DNA - for cash

IT'S like something out of *2001: A Space Odyssey*. An artefact buried on the moon conceals a big secret. Only this time, the secret is you...

A plan to establish a lunar archive containing human DNA and a digital record of life on Earth is being unveiled this week.

Called Lunar Mission One, the archive is the brainchild of British space consultant David Iron, who has worked on Skynet, the UK spy satellite network, and Galileo, the European Union's global positioning system. His idea is to charge people £50 or so to place a sample of their DNA, in the form of a strand of hair, in an archive to be buried on the moon, alongside a digital history of as much of their lives as they want to record, in the form of text, pictures, music and video.

Iron presented his plan at a space flight conference at the Royal Society in London on 19 November.

The catch? He needs at least 10 million earthlings to do this if he is to generate the £500 million the moonshot will need.

This week, Iron and his colleagues will launch a crowdfunding campaign on Kickstarter.com to raise the initial £900,000 of seed funding needed to set up the company that will begin commissioning designs for the spacecraft, which it is hoped will blast off in 2024.

Working with the Rutherford Appleton Laboratory in Harwell, UK – which regularly works on NASA and European Space Agency missions – Iron aims to piggyback the archiving venture on a genuine space science

mission. First, Lunar Mission One plans to land a robotic spacecraft on the moon's south pole. It will then drill at least 20 metres into the lunar crust, extracting core samples to be analysed on the craft in an attempt to better understand the moon and its ancient relationship to Earth.

"Getting below that top layer of the moon that Apollo looked at should give us extraordinary new data," he says.

After about six months of such

"Being able to point up at the moon and say 'there's a bit of me up there' will have a lot of appeal"

science, capsules containing the DNA and digital data will be injected into the borehole, which will then be sealed. Some of the archive will be a record of Earth's history, civilisations, culture and inhabitants. The rest of the archive, the private record, will come from millions of

individual customers, Iron hopes.

Another space flight venture plans to send religious artefacts to the moon, as *New Scientist* reported in May (bit.ly/1oZnXqU). The Church of England has even told Iron that the plan to store DNA on the moon does not conflict with Christian doctrine. "It is beyond religion," Iron notes.

"I'm intrigued. This lunar time capsule might be a lot of fun," says Roger Launius, a director of the Smithsonian National Air and Space Museum in Washington DC. "The idea of being able to point up at the moon and say 'there's a bit of me up there' will have a lot of appeal."

The hope is that the archive can serve as a sort of "backup drive" for human civilisation. But extracting DNA from hair may be challenging, says Alan Cooper at the Australian Centre for Ancient DNA at the University of Adelaide. For long-term storage, DNA from cheek cells or blood would be more stable. Paul Marks ■

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Losing its cool

Climate pledges won't be enough

Catherine Brahic

IT HAS been a remarkable fortnight for climate change announcements. First came coordinated Chinese and US promises to cut their greenhouse gas emissions. Then the US and Japan pledged a total of \$4.5 billion to an international fund to help poorer countries deal with global warming.

The moves are being made ahead of the next round of international climate talks, which kick off in Lima,

Peru, on 1 December. The big question is will they be enough to help keep global warming below 2°C, a politically agreed threshold generally deemed to represent the level of dangerous climate change.

Recent analyses suggests not. But the news for optimists is that both the US and China could cut their emissions sufficiently to help keep the world under 2°C of warming simply by adopting the best practices of other nations - and that includes

learning from each other.

So say researchers involved in the international Climate Action Tracker project (CAT). Prior to last week's pledges on emissions cuts, the group estimated that promises around the world, if they are kept, leave us on track for 3.7°C of global warming, a far cry from the internationally agreed limit of 2°C.

Last week's promises by US and China - which are jointly responsible for over a third of global emissions - will nudge us closer to 2°C, says Niklas Höhne of the New Climate Institute, one of CAT's participating institutes. A nudge, of course, is not enough.

Importantly, he says, getting back on track for 2°C is not out of reach for either nation. The CAT examined the

best practical efforts to cut emissions around the world - from electric cars and new building standards to transforming cement production.

Chinese cement factories are the most energy efficient, whereas the US leads the world for standards in iron and steel factories. Höhne says the aim of the study was to give a realistic sense of what could be achieved today without requiring new research and development. "Our benchmark is what another country has done," he says.

The team found that adopting global best practices would set China on track for peak carbon dioxide emissions by 2020, a full decade earlier than they promised last week. And US president Barack Obama's promise to cut emissions by between 26 and 28 per cent below 2005 levels by 2025 could materialise, if the US adopted the global best practices.

"We are very confident that if the US and China did this, they would be on pathways compatible with 2°C," says Höhne.

Changhua Wu, a Chinese analyst with The Climate Group international think tank, says the CAT's estimate may be optimistic. But she is adamant that Chinese ambition could be raised further if there were a concerted international effort.

No country on its own can curb global emissions enough to stay below the 2°C threshold, so nations must work together. The actions of the US and China should have the power to drive the ambition of other nations. ■

Mixing senses: synaesthesia taught to adults

BRAIN training for synaesthesia - where you mix up sensory information - may be just around the corner. People have been taught to experience a form of synaesthesia in which letters appear as certain colours, in their everyday life.

By the end of the nine-week course, most of the volunteers were seeing text in the real world take on particular hues, on road signs, for example.

"The colour immediately pops into my head," said one participant.

Synaesthesia is thought to result from people's brains developing in such a way that their sensory signals get mixed up. So "Tuesday" might evoke the colour pink, for example, or the word "tree" might taste like popcorn. Early life experiences may play a role - some synaesthetes report that their letter-colour pairings match the colours of a childhood alphabet or fridge magnets. But is it something you can learn as an adult?

Two years ago researchers induced some aspects of the condition by getting people to read books where

some of the letters appeared in certain colours. This improved their scores on tests but didn't translate out of the lab.

What if people underwent more intense training? Daniel Bor at the University of Sussex, UK, gave people daily half-hour training sessions to teach them 13 letter-colour associations, using progressively harder tasks. The volunteers also practised with specially coloured

"By the end of the training, people were seeing text on road signs take on particular colours"

e-books. As well as passing the lab tests, 9 of the 14 volunteers reported seeing coloured letters to varying extents when they read ordinary black text. Many saw effects by week five, and some had synaesthetic experiences daily. Their prowess faded once the training stopped (*Scientific Reports*, doi.org/w7j).

The training had an unexpected benefit too. The volunteers gained 12 points in IQ tests by the end of training. However, this may be a general benefit of intensive training with memory-related tasks, says Bor, who adds that he may in future put the training tools online. Clare Wilson ■



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Warming world will bring millions more lightning bolts

GOLFERS beware. Expect more lightning bolts as the world warms up. Millions more.

We already know that climate change is increasing the likelihood of storms, tornadoes and heatwaves. Now a model of how climate change will affect lightning patterns in the US predicts that the number of lightning bolts will increase by 50 per cent over the next century.

"For every two lightning strikes in 2000, there will be three in 2100," says David Romps at the University of California, Berkeley, who led the study. In the worst-case scenario, with 5 °C of global warming, lightning strikes

could more than double (*Science*, doi.org/w5k).

There are already 25 million lightning strikes per year in the US, killing approximately 100 people and igniting half of wildfires. More lightning potentially means more strikes on people and buildings, and more wildfires.

Romps's team developed a model that uses data on rainfall and storm energy to predict lightning and validated it against real-world lightning data from 2011. They then applied it to 11 standard projections of climate change, which range in predicted global warming from 2.5 °C to 5 °C to predict future lightning patterns.

Romps now hopes to work out how the additional lightning will be distributed to help predict changes to wildfire frequency. And he is optimistic that the same model could be applied to other regions of the world.

Habitable moons born in collisions

FROM Endor to Pandora, habitable moons are science fiction staples. Trouble is, they seem hard to make in the real world. But hit-and-run accidents involving planets could create moons able to hold on to an atmosphere.

Previous studies suggest that a world must be at least a fifth of Earth's mass to sustain an atmosphere. If moons form from dust discs surrounding a planet,

it seems only planets 10 times the mass of Jupiter will have sufficient material in their discs to build moons heavy enough to have air.

Large objects crashing into rocky, larger-than-Earth planets can form more massive moons by blasting material into space. Our own moon formed that way, although it is not a heavyweight so has virtually no atmosphere.

At the American Astronomical

Society's Division of Planetary Sciences meeting in Tucson, Arizona, last week, Miki Nakajima of the California Institute of Technology in Pasadena presented models of planets colliding with objects a tenth of their mass. For rocky planets up to five Earth masses, the impacts formed silicate-rich moons of up to a fifth of the mass of Earth.

"This is small, but actually we might be able to observe these moons," she says.

'Good viruses' may help protect gut

VIRUSES have a bad rep, but some may help protect the body from illness, much like the "good bacteria" that dwell in our gut.

A team led by Ken Cadwell at New York University gave a group of mice the rodent equivalent of norovirus. They were then given antibiotics, which wiped out much of their gut flora, before ingesting a potentially fatal gut-irritating chemical. Those with the virus were much more likely to survive than those that hadn't been infected with it.

Next, the team gave other mice antibiotics prior to infecting them with a bacterial pathogen. Of these mice, those then given the virus showed far fewer signs of illness than those not given it. Cadwell says this suggests the virus helps protect against infectious and non-infectious gut problems when bacteria aren't around to act as a defence (*Nature*, DOI: 10.1038/nature13960).

I don't need Glass, I've got contacts

CONTACT lenses that can display video and detect health problems in pilots could one day be created using a 3D printer.

Michael McAlpine at Princeton University and his colleagues have developed a 3D printer that can make a five-layered contact lens that emits light into the wearer's eyes (*Nano Letters*, doi.org/w5p).

To prove the principle, they embedded a transparent polymer with quantum dot light-emitting diodes, plus wiring made from silver nanoparticles, and organic polymers that could act as circuit components.

The work was funded by the US air force, which hopes to use such lenses to display in-flight data, or to detect fatigue and health problems in pilots.

Starfish ripper suspect identified

GUILTY AS CHARGED? A mysterious epidemic ravaging sea stars on North America's Pacific coast has had scientists scratching their heads. Now they have a prime suspect. The discovery is the first step in helping researchers learn what triggered the outbreak.

When sea stars began dying in great numbers last year, all the way from Mexico to Alaska, some researchers called it the biggest marine disease outbreak ever recorded. Now a team led by Ian Hewson of Cornell University in Ithaca, New York, is building a case against a type of parvovirus called a densovirus. Their experiments in aquaria showed that infection was transmitted by virus-sized particles, and that heat sterilisation of the particles – which kills viruses – prevented infection.

To identify the virus, the team sequenced viral DNA and RNA from infected and healthy sea stars. One virus, the densovirus, turned up much more frequently in diseased sea stars, and the amount of virus present increased as the disease progressed (*PNAS*, DOI: 10.1073/pnas.1416625111).

However, the team didn't find densovirus in every infected sea star. Hewson thinks this may be because some sea star samples just happened to contain no infected tissue. The trial continues.



FRED BAVENDAM / MINDEN PICTURES

Dark matter could be seen in telltale GPS time glitches

GPS has a new job. It does a great job of telling us our location, but the network of hyper-accurate clocks in space could be about to get a fix on something far more elusive: dark matter.

Dark matter is thought to make up 80 per cent of the universe's matter but scarcely interacts with ordinary matter. A novel particle is the most popular candidate, but Andrei Derevianko at the University of Nevada, Reno, and Maxim Pospelov at the Perimeter Institute in Waterloo, Canada, propose that kinks or cracks in the

quantum fields that permeate our universe could be the culprit.

If they are right, fundamental properties such as the mass of an electron or the strength of electromagnetic fields would change at these kinks. Clocks would measure time slightly differently as a result.

That's where GPS comes in. The satellite network is about 50,000 kilometres in diameter, and is travelling through space – along with the entire solar system – at about 300 kilometres a second. So any time shift when

the solar system passes through a cosmic kink will take at most 170 seconds to move across the network, the team calculates (*Nature Physics*, doi.org/w66). Other things could perturb GPS timekeeping, but only a dark matter signal would have that signature, they say.

Derevianko is already mining historical GPS data for dark matter's fingerprints. If that fails, he plans to extend the search using a ground-based network of even more sensitive atomic clocks being built in Europe.

Hacked cells store analogue memories

BACTERIA have had their DNA hacked so they can store memories of their environment, similar to an old tape recorder. It lays the path for tiny cellular biographers to track diseases like cancer or irritable bowel syndrome.

DNA sequences in *E. coli* called retrons code for enzymes that generate new strands of DNA. These strands insert themselves into the bacterial cell's genome. Timothy Lu and Fahim Farzadfar at the Massachusetts Institute of Technology manipulated retrons so that when the *E. coli* is exposed to an input such as a light pulse, a new chunk of DNA is inserted into a specific place. That DNA acts as a "memory" of the experience.

They designed the retrons to be only partially efficient, so only a few cells record the memory. As the input's length of exposure increases, more cells respond – so seeing how many carry the memory tells us about the input's duration (*Science*, doi.org/w5h).

Other DNA memory systems exist but all store data digitally as discrete all-or-nothing values. An analogue system allows more to be recorded as the signal builds up over time, says Cameron Myhrvold at Harvard University.



INCO ARNDT/NATUREPL

Big balls a sign of mammal infanticide

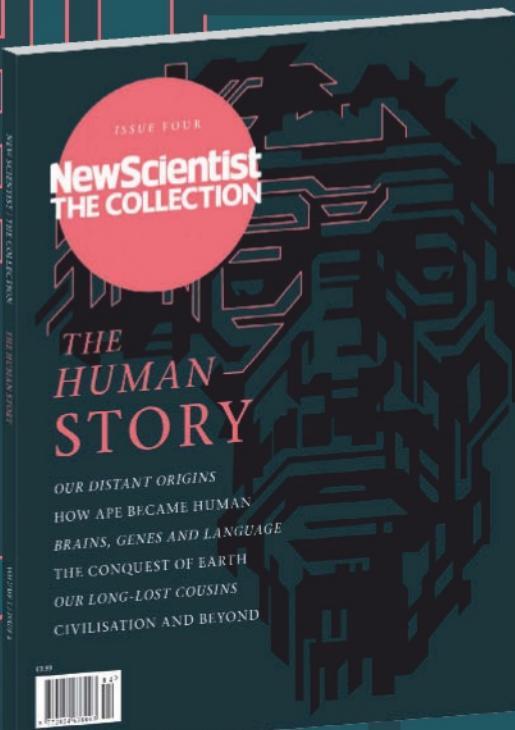
GREAT BALLS OF FURY. Large testicles could be a giveaway sign that the males of a species are given to killing their rivals' offspring.

Dieter Lukas of the University of Cambridge and Elise Huchard of the University of Montpellier in France built a database of behaviour covering 200 mammal species, and mapped it on to the mammalian family tree.

They found that infanticide was most frequent in species that live in groups where a few dominant males monopolise opportunities to mate with the females. The privileged

status of these males doesn't last, however. "The males don't manage to stay dominant for very long, so when they can mate with the females, they need to do it as quickly as possible," says Huchard.

The researchers found a strong correlation between infanticide and testicle size (*Science*, doi.org/w5g). A female evolutionary response to infanticide is to become promiscuous, which blurs the paternity of their offspring. That in turn forces males into a race to produce more sperm and boost their chances of fatherhood, so they grow larger testicles.



The evolution of a genius ape

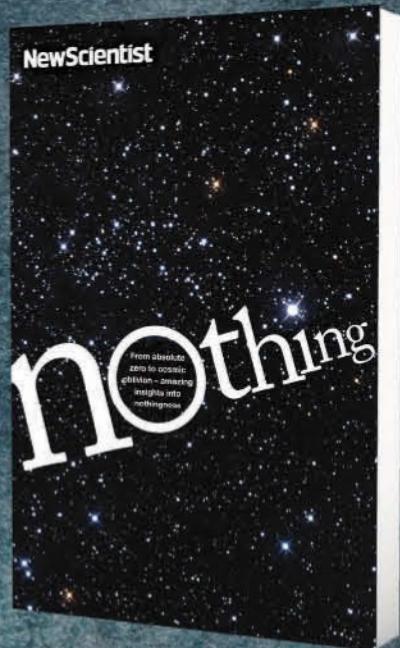
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Hackers fight Ebola

Innovative software and other tools can help rein in a virulent disease where medical staff are thin on the ground

EBOLA has a new enemy: an army of hackers. Alongside health workers and fast-tracked vaccines, software developers are now part of the campaign, putting together novel tools which could save lives.

Earlier this month, teams of physicians and graduate students from various disciplines spent a weekend huddled round laptops and drawing boards in the Saïd Business School at the University of Oxford. The aim of the Ebola Crisis Hackathon was to develop software and systems to help West African communities devastated by the worst-ever outbreak of the disease.

One such tool is a program which automatically detects people appearing in a video feed and measures their pulse using image analysis. "The idea is to be able to do contactless triage," says

Paul Brodersen, a researcher in systems biology, who showed off the system.

The technique is called Eulerian video magnification and it works even with a basic webcam. Brodersen's software – based on freely available code developed at the Massachusetts Institute of Technology and Quanta Research in Boston – works by amplifying the red tones in a person's face. The subtle variation in redness over time gives away the pulsing of blood beneath the skin.

When combined with handheld infrared thermometers already in use in the affected countries, the system allows people to be quickly assessed and then sent for the most appropriate treatment at health centres. That's because there is a characteristic slowing of the

pulse as the fever seen in Ebola reaches its peak.

Garfee Williams, a Liberian doctor who works for the charity Africare, has been involved in the fight against Ebola since the current outbreak began in March. He is impressed with this form of triage. "It would boost the confidence of our health workers,

"The subtle variation in the redness of a face over time gives away the person's pulse rate"

who would know they are working with a tool that means they don't have to have lots of contact with patients," he says.

For the system to be useful, however, there must be health workers in place. With this in mind, another team at the

hackathon has come up with a real-time map displaying the locations of Ebola cases and medical staff. The idea is to show where suitably trained health professionals need to be stationed in order to contain an outbreak most effectively.

Slowing the spread

Williams says that even small changes in the placement of doctors can have a significant impact on Ebola's spread.

"By just increasing numbers of health workers at some outposts from two to four, we see results like fewer people becoming sick in that area," he says.

One member of the mapping project is programmer Chris Rex, who previously worked with the New York Police Department to create a live map of police officers' locations. "If we can improve transparency and let people know where the resources are, you can do a much better job of helping them make operational decisions," he says.

But before you can map where doctors are, you need to know just who they are. This is where team leader and medical doctor Alexander Finlayson of the University of Oxford, comes in.

Finlayson recently helped establish the MedicineAfrica social network, which covers Somaliland. He's hoping to extend the platform to compile a database of West African doctors in the midst of the Ebola crisis, information which can then be plugged into the live map.

What about situations when doctors and nurses just aren't available at all? In Sierra Leone, for example, there are 45,000 people for every doctor. A system which helps members of the public assess their own symptoms could be of help.

The idea is to use a simple questionnaire sent by text message to evaluate symptoms and place people in one of four risk categories. Basic questions ➤

such as "do you have a fever?" are followed by questions that look at epidemiology, such as "have you taken part in a burial ritual recently?" Coming into contact with the bodies of Ebola victims during funerals has allowed the disease to spread, so a simple yes or no answer, also sent by SMS, would move the respondent along a flow chart of risk factors.

Advice by text

"We categorise you into a risk group and then we give you advice," says student Mark Gilbert. "Based on that, you stay in our database so we can provide more automated services. The patient's telephone number acts as a unique identifier."

Like Brodersen, Gilbert has relied on freely available software, in this case RapidSMS, which lets coders build SMS-based services that they control via an online dashboard.

All of the teams are looking to gain the support of an aid agency and, in some cases, additional funding to take their projects forward. Gilbert and his teammates, for example, have already contacted aid organisations such as Oxfam and Médecins Sans Frontières to try to fast-track their idea.

Hilarie Cranmer, technical adviser on Ebola to the non-profit International Medical Corps (IMC), says hackathons are a great way to speed ideas to the frontline of a disease outbreak. "Any innovation towards record-keeping or communications, those are fantastic," she says, adding that knowing how to implement such schemes is the hard part. The IMC is holding its own Ebola hackathon in Boston next month.

For Williams, having a better way of understanding the crisis unfolding all around him is vital. "It would let us be much more responsive in the communities," he says. Chris Baraniuk ■



Sounds suspicious

LOOP IMAGES LTD/ALAMY

The walls have ears

Listen in to protect your home, says **Chris Baraniuk**

IF A window breaks in your home while you are out, will anyone hear it? A sensor that analyses the ambient noise in your house promises to provide a watchful ear.

Developed by Form Devices in Malmö, Sweden, the internet-connected device, called Point, looks like a wall-mounted smoke alarm but packs an acoustic sensor that measures background noise.

"We live in apartments and don't need full-blown security systems. The only real options were cameras and surveillance tools and we didn't want that," says Nils Mattisson of Form Devices. "All you need to know is that everything is fine and no accidents have happened. You can pick that up using sound alone."

Point listens for specific sounds in frequency ranges that it has been programmed to recognise, such as breaking glass. When it notices something, it alerts the homeowner via a smartphone app. Form Devices claims it can detect whether people are present in your home when you aren't there, which could indicate a

burglary in progress. The firm hopes to add the ability to recognise other sounds as well, such as doors being opened and closed.

Point also includes temperature and humidity sensors as well as a system for analysing airborne particles. Mattisson claims this can differentiate between smoke from a smouldering source like overcooked food and smoke from an actual fire.

On 4 November the team launched a Kickstarter crowdfunding campaign and had more than tripled its \$50,000 goal when *New Scientist* went to

"All you need to know is that everything is fine when you are away - you can pick that up using sound alone"

press. The device is due to ship to consumers in mid-2015.

Analysing sound to detect problems isn't new – various researchers have explored the potential for analysing internal combustion engine noises to

diagnose mechanical problems automatically, for example. Applying a similar process to the domestic environment could give homeowners peace of mind.

David Bryan at security firm Trustwave says using sound to detect break-ins isn't a new approach, but bringing it to the average consumer is.

There is a huge market among people who let their homes out to strangers for short periods of time, Bryan says, such as through services like AirBnB. The device can be set to glow yellow when it detects loud music or someone smoking a cigarette. The feature could be used as a warning to guests who are ignoring house rules that if they keep it up, the owner will soon be notified.

But it would be important to ensure the device couldn't be hacked over the internet, says Bryan. "You would want to make sure that a malicious hacker couldn't turn the audio sensors into a makeshift microphone or irritating device with a constantly activated alarm." ■

Radar network makes tigers good neighbours

THE tigers in India's Panna National Park will soon live in a forest that watches out for them. A wireless network of low-power radars is being developed to track everything that moves in or out of the forest. This helps keep the tigers safe from poachers, and villagers' cattle safe from the big cats.

Built by Anish Arora at Ohio State University in Columbus, the work was originally designed as a way for the US government to monitor the flow of people across the country's borders. Had the US border patrol not opted to build a 1100-kilometre-long fence instead, the system could have alerted officers to people trying to cross the border with Mexico anywhere other than at official points.

Arora's system is the first wildlife-tracking technology that detects and reports on a specific animal in real time. It works by looking for the patterns created as radar reflects off different objects, and then comparing these to recorded signatures. When the system spots a human entering the tiger's reserve, or a tiger leaving, it alerts the wardens.

"It is as simple as that. The alarm goes off and poachers get caught," says Arora. Or guards posted inside the 400-square-kilometre park can move to cut off a tiger that is advancing towards a farm. When the

system is fully up and running, Arora says, it will cover all the most tiger-trafficked parts of the forest.

It's not the only technology on the lookout in Panna. P. Vijay Kumar of the Indian Institute of Science in Bangalore is working on an infrared system that ignores swaying trees and shrubs, and sounds the alarm only when it detects an intruder. M. Radhakrishna at the Indian Institute of Information Technology in Allahabad is burying fibre-optic cables that detect slight changes of pressure at the surface.

"When the system spots a human entering the tiger's reserve, or a tiger leaving, it alerts the wardens"

The step of a human or tiger makes the fibre bend slightly, changing the way light moves through it.

When it comes to imaging, Arora's radar system has a big advantage over cameras. Gathering and processing radar data takes less computer power than visual images do, allowing the network to keep running day and night for long periods of time. "It can survive on very little power, a couple of AA batteries," Arora says. He plans to put an updated version of the network live for several months starting in December (*SenSys 2014*, doi.org/w5b). Hal Hodson ■



SUBHORANJAN SEN

ONE PER CENT



Climb walls like Spider-Man

Who needs stairs? Regular humans can now scale vertical walls. Elliot Hawkes and his team at Stanford University, California, used a plastic called PDMS that forms large sheets covered in fibres that work just like the hairs on geckos' feet. These hairs produce intermolecular van der Waals forces, letting them stick to surfaces (*Journal of the Royal Society Interface*, DOI: 10.1098/rsif.2014.0675). Attached to handheld pads, the plastic lets human climbers shimmy up a vertical glass wall.

"The technology is moving faster than the international response"

Mary Wareham at Human Rights Watch on the danger of killer robots. On 14 November, 118 nations agreed to discuss the issue further at a UN meeting next April

Great wall of humanity goes on holiday

The greatest human migration on Earth isn't the hajj - it is people in urban China going home for Chinese New Year. This year, the country's internet giant Baidu gathered location data from more than 200 million smartphones as their owners made journeys. Extrapolating from this, they estimate that 3.6 billion trips were made during the 34-day festival season. City dwellers accounted for most of the journeys, heading for the country and then returning, mainly to Beijing, Shanghai and bustling Guangdong province (arxiv.org/abs/1411.0983).

Film a finger, find your blood pressure

Smartphones can peek inside your body. Researchers at India's Tata Consultancy Services built a system that measures blood pressure from a close-up video of a fingertip, taken on a smartphone. Software counts the total number of red pixels in each frame, and how each pixel changes over time. It uses those numbers as a proxy for the rate of blood flow and pressure. The device can measure blood pressure to within 10 per cent of the accuracy of a clinical cuff.

INSIGHT Charity

Time to donate direct

Tech start-ups are role models for charities, finds **Rachel Nuwer**

CHASE ADAM, a Peace Corps volunteer, was bumping along a road near the Panama-Costa Rica border when a woman boarded his bus. Clutching her son's medical records, she asked each passenger for a small donation to help fund his treatment, which she couldn't afford. To Adam's surprise, nearly every passenger donated.

The woman was essentially crowdfunding her son's treatment, Adam realised, but she was restricted to asking only those around her for help. What if there was a way to expand that approach by tapping into the global community?

Inspired, Adam co-founded Watsi, a non-profit organisation named after the town where the woman boarded the bus. He describes it as "Kickstarter for healthcare around the world" as it uses crowdfunding to pay for treatments for those in need, identified by hospitals that work with Watsi.

Since launching in 2012, Watsi has funded healthcare for nearly 3000 people in 19 countries. Earlier this month, it launched the Universal Fund, a recurring monthly donation system that distributes funds to those who need it most. So far, nearly 700 donors have signed up.

Watsi isn't the only non-profit modelling itself on technology start-ups rather than traditional charities. Donors Choose enables backers to fund US school projects; Kiva allows you to lend small amounts of money to individuals in developing countries and Omakase handpicks charities for donors to support each month.

"We're different to traditional non-profits that have long cycles of grants and projects, and feedback that happens over years rather than days or weeks," says Shivani Garg Patel, co-founder of Samahope, which raises funds to support individual doctors in developing countries, especially those who are treating women and children.

After raising more than \$1 million from Silicon Valley philanthropists to get Watsi off the ground, the team behind the project is now supported by optional tips from the site's users, which account for 8 per cent of all donations. Samahope donors can also give part of the sum to the organisation, which keeps the site going alongside funds from foundations and businesses.

Whether these approaches will be sustainable or more effective than

traditional non-profits remains to be seen. "There's almost a cult of innovation here," says Lucy Bernholz at the Stanford University Center on Philanthropy and Civil Society. "So even if something is working and has been around for a long time, the zeitgeist is almost 'if it works, break it'."

The crowdfunding model is best suited to charity work that delivers an instant reward, she says - a patient healed, a life saved - rather than projects tackling things like poverty and inequality, or ones that require

"People don't just want to know where their money goes - they expect to meet the people who benefit"

scientific research, which may take years to come to fruition. "The downside is that we start loving things that allow us to check off boxes and give us instant gratification," Bernholz says. "Finding long-term support for structural changes is the bigger question."

Grace Garey, Watsi's co-founder, acknowledges that crowdfunding isn't the only business model for charities. "But I do think that every non-profit will have to fall in line with this idea that technology is making the world smaller," she says. "People don't just want to know where their money goes - they expect to meet the people on the other end." ■

Statistical and causal approaches to machine learning

2014 Milner Award Lecture given by Professor Bernhard Schölkopf, Max Planck Institute for Intelligent Systems

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APERTURE



Hermit style

PATIENCE, says Susan Middleton, is the most important aspect of her photography. "My subjects are difficult to see even for the most experienced divers and marine biologists - many are small, many are cryptic and hide, many are masters of camouflage."

Middleton has spent seven years cataloguing the diverse range of marine invertebrates found across the Pacific Ocean as photographer on scientific surveys and censuses. The results are collected in her new book, *Spineless*.

This is a gold-banded hermit crab. Hermit crabs don't grow their own shells, but upcycle those of dead molluscs. As a result, the shells they inhabit often show signs of wear and, as in this case, colonisation by other animals: on the left and right sides of the shell are anemones, with barnacles and tube worms also attached.

Hermits aren't often seen without their shells. They leave only when another is available to move into immediately, because they are soft and vulnerable without them - as you can see in the image below. This candid snap is the animal equivalent of an intrusive long-lens shot you might see in a tabloid.

"This is our home planet and these are our distant cousins," says Middleton. "In the course of the fieldwork, several new species were discovered, since this realm of life is relatively unknown, yet we depend on it for our own survival." Rowan Hooper



Photographer

Susan Middleton susanmiddleton.com

From her book *Spineless: Portraits of marine invertebrates, the backbone of life* (Abrams, 2014)



Tragedy in the making

The world risks heading the way of Easter Island – a spiral into conflict as depleted natural resources are plundered, warns **Petros Sekeris**

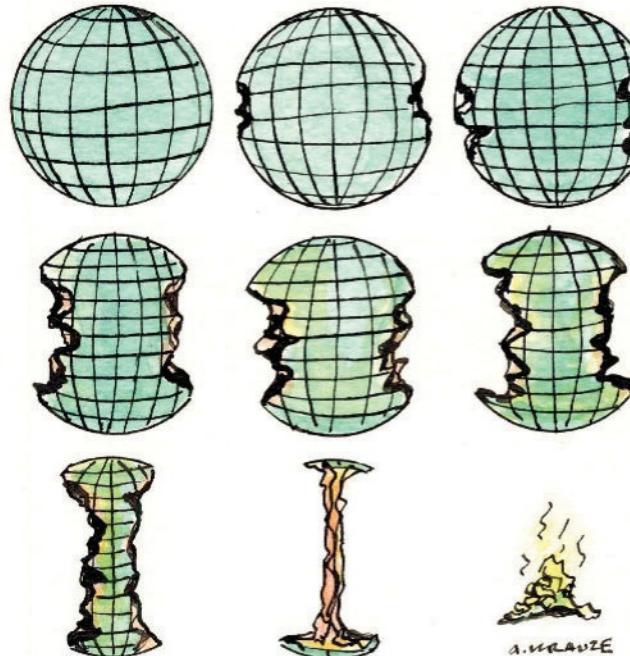
THERE is a growing feeling that resources vital to sustain human life, such as fresh water, land and fossil fuels, are being used too fast to ensure our long-term presence on the planet. It seems obvious that nations should cooperate on this problem, and yet successful cross-border solutions and agreements are hard to find. Why don't we act for the common good more often?

Look around the world and you can see instances of water-related inter-state tension and conflicts in many regions, including the Middle East (Jordan river basin, Tigris-Euphrates basin), Asia (Indus river), and Africa (the Nile).

"Fish wars" have erupted sporadically, such as Europe's cod wars, and while these have been more contained, they could resurge amid decreasing stocks. In the same way, the shared resource of global climate continues to be threatened by the relentless burning of fossil fuels.

Our degradation of the environment is ominous and much evidence points to a clear link between the scarcity of vital resources and conflict. One wonders, then, why world leaders failed to reach a substantive agreement on climate change at the Copenhagen summit in 2009; or why fishing and hunting quotas for endangered species are so hard to implement; or why the use and pollution of river basins is not better regulated.

Explanations such as poor forecasting of resources, the short-term mindset of politicians, or simply the refusal to recognise



the problem are usually given.

However, what if these are not the real reasons and something more fundamental is at work? Game theory, an established way of modelling decisions involving conflict and cooperation, offers a way to seek answers. Traditionally, cross-border armed conflict over shared resources is sidelined in game theory simulations on the grounds that it is deemed more costly to a nation state than cooperation.

For example, imagine a depletable natural resource – such as a water basin – jointly owned by two countries. Both drain it for drinking, sanitation, irrigation and so on. Draining too quickly will result in it drying out.

Most game theory work says that working for the common good is the optimum choice for both nations. But this does not square with conflicts we see, or the widely held view that more are inevitable.

To address this, I designed a simulation that allowed the use of violence to control resources (*The Rand Journal of Economics*, vol 45, p 521). In a world where force is a very real option and history suggests it is used or threatened more often than we might hope, this seemed reasonable.

The outcome offers an

"Stronger institutions and international bodies are needed to avert a tragedy of the commons"

explanation for the gap between theory and reality. Having constructed a game-theoretical model, I found that when conflict is allowed it *always* occurred, but only when resources become heavily depleted.

And, crucially, the very expectation of impending conflict led to non-cooperation in the short term and sped up depletion of the common resource. I would argue that this resource-grabbing tallies with what we see in much of the world, be it disputes over fossil fuels, fresh water, land or marine resources.

Are there any historical examples that illustrate this effect of "conflict expectation" and more rapid resource use? Possibly. The demise of the first society on Easter Island, as documented by Jared Diamond in his book *Collapse*, is salient. It is thought Polynesians were first to colonise this isolated, 160-square-kilometre Pacific island around AD 900. At its peak, 30,000 people may have lived there.

Their society was organised in hierarchical clans, peacefully competing for supremacy by displaying vast stone statues. To move them, the tallest trees needed to be felled and used as rollers. Deforestation resulted, says Diamond. Instead of reaching agreements, the islanders rapidly devastated their lands, and by the time the first Europeans arrived in 1722, no tree taller than 3 metres stood there.

An ecological disaster and dramatic deprivation must have occurred. According to Diamond,

a sort of military coup took place, sparking prolonged conflict. It is reasonable to imagine that the clans realised that trees – also vital for things like fishing boats – were in short supply, and so grabbed what they could before the inevitable violence.

The conclusions I've drawn on the impact of over-use of resources today on future conflict are purely theoretical. So with economists Giacomo De Luca and Dominic Spengler of the University of York, UK, I am designing a lab experiment to see whether humans in a controlled environment do deplete resources faster when given the possibility to use violent control. Our early findings point that way. Such evidence would shed new light on the failure of international cooperation over the preservation of the environment.

What's next? I have not yet considered human ingenuity in adapting to a changing environment. Whether that will be sufficient to achieve a sustainable path depends on the rate of depletion versus adaptation.

Inevitable conflict and accelerated use of depleted resources may be more likely to become a reality within weak states and in the international arena, where weak institutions are more likely. For example, signing a carbon emissions treaty today does not commit a country beyond mild sanctions that the global community may or may not impose. In addition, a change in government in a powerful country is sufficient for a treaty to be revised, curbing the incentives of others to join.

All this reinforces the need for stronger institutions and international bodies if we are to avert a tragedy of the commons in a violent world. Sadly, this will require overcoming the very problem we are trying to solve: a lack of international cooperation. ■

Petros Sekeris is an economist at the University of Portsmouth, UK

ONE MINUTE INTERVIEW

No chickens required

Josh Tetrick's egg-free mayo is just the first in a line of planet-friendly products. What is the secret ingredient?



PROFILE

Josh Tetrick founded Hampton Creek, a San Francisco start-up that uses plants to replace eggs in food products. His egg-free mayonnaise Just Mayo hits Tesco supermarkets this month

You're creating egg-free versions of popular foods such as mayonnaise. Why?

The vast majority of food we buy today is surprisingly cheap and tastes pretty good but is bad for our bodies and destructive for the planet. Most people aren't choosing that because they're uncaring. We think they're choosing it because it's easy. Our vision is something different.

What's bad about using eggs in mayonnaise?

It's radically inefficient. Growing soya and corn to feed chickens, in particular, requires an enormous amount of land, water and energy.

How do you get people to eat egg-free mayo?

Our theory is you don't convince people to do the right thing. We think you change the world by making the good things so obscenely better it's foolish not to do it. We don't think people are going to eat our mayonnaise because it doesn't have eggs in it. People are going to eat it because it tastes better, lasts longer and is more affordable. It only works if you win on the merits.

How do you find a plant that can take the place of egg?

I started this knowing nothing about the world of biochemistry or food science. We brought in some biochemists and they ran tests, looking at the molecular weight of plant proteins, the solubility, all sorts of different properties. We identified one plant, a cultivar of the Canadian yellow pea, that's a particularly good element in a mayo system.

With so many plants, where do you start?

There are a few filters that we have. We like to look at species that are already called GRAS species, which stands for generally regarded as safe, at least according to the US Food and Drug Administration. We prefer plants that don't require a lot of water for two reasons: it's expensive and the world is facing a water shortage. We don't like plants that use a lot of land because that's an issue. And we don't want a plant with a funny name. If it sounds funny my grandma is not going to buy the mayonnaise at Walmart. We can't change the name of the plant.

And now you've got data experts involved. What are they doing?

We can't manually screen 400,000 plants. You need a more data-driven approach. Every species has lots of subtypes. In each of the cultivars, we're looking at different properties of the protein. There are lots of variables. And then we're trying to connect those data points with functions like: does it emulsify, does it aerate, does it gel in a pan, does it actually taste good when it crunches in your mouth? The data scientists can make intelligent connections using all that data.

What are you looking for next?

We like the idea of creating a fundamentally better pasta, one that uses a lot less water and land and is better from an animal welfare perspective. And then we've identified a plant that scrambles like a chicken egg and that is going to be released fairly soon too.

Interview by Niall Firth

How not to be wrong

Science is plagued by bias, sloppy methods and dodgy statistics. **John Ioannidis** has dedicated his career to pointing out the flaws and getting rid of them

Nearly 10 years ago you caused a stir when you showed that most published scientific findings are wrong. Have things improved since then? We have seen lots of improvement. Some fields have made more progress than others, but many scientists have been sensitised to the issues that compromise good research and are trying to come up with solutions.

So scientists didn't take it personally?

A few may have been annoyed. But I'm not interested in shaming individuals. I'm interested in the big picture – in showing problems that may affect many thousands of papers. If you say a single paper is wrong, that can easily get you into trouble. It's different when you say that all of the papers are wrong.

In what way have things improved?

Many disciplines have moved to a team approach, so scientists across the field work together, share data and repeat the original study to see if they arrive at the same results. Such changes have transformed human genome epidemiology from an unreliable discipline with a 99 per cent non-replication rate to one with a 99 per cent replication rate, for example.

It would be interesting to further assess the value of replication to understand when, how and by whom it should be done. Right now I'm collecting data to see if solutions that work for some fields could also apply to others.

Why is replication still rare?

It may be entrenched tradition. The dominant paradigm has been that, to be a good scientist, you shouldn't do what has been done before. I'm not saying this is completely wrong. We do need different approaches to the same

question. But if we have no replication then everything we do is unclear. In fact, the psychological sciences just went through a crisis because, when people finally did try to replicate some key findings, they found that they couldn't.

Are some disciplines more susceptible to flawed research?

All scientific fields face challenges, but they have adopted safeguards to different extents. Many of the physical sciences use large-scale collaboration, for instance. They also have a culture where the credibility of a finding has to be very high before they publish it. In biomedical disciplines, if you find something even nominally significant, you publish it.

That said, I don't think standards should be exactly the same across fields. The question is whether we can convey that a finding is of low credibility, that "this is interesting, but it's just 1 per cent likely to be true – it needs to be replicated and we will have to wait".

Your proposed solution is to introduce a credibility estimate. How might that work?

Each scientific paper and major result would have a credibility estimate based on the quality of the research. So for the finding that smoking causes lung cancer, the credibility estimate would be 99.99999 per cent. Conversely, for findings where we have only seen a few cases that drug X may cause severe bleeding, for instance, the credibility estimate might be 1 per cent. It may still be worth publishing because it is important to make sure the drug doesn't cause severe bleeding.

At the moment we have no guidance when we see yet another paper that claims to have "significant results". Nearly all papers in the

PROFILE

John P. A. Ioannidis is co-director of the Meta-Research Innovation Center at Stanford University, California, and also professor of disease prevention, health research and policy, and statistics. He studies ways to improve scientific credibility, most recently in the journal *PLoS Medicine* (vol 11, p e1001747).



biomedical sciences claim significant results – but even so we know that less than half of findings get replicated.

Could credibility estimates stifle research?

Weird, extravagant, bold ideas should be out there, presented with whatever evidence there is. We cannot wait for perfect certainty; there is no such thing in science anyway. I am happy to see low credibility papers published, otherwise we do risk stifling scientific advances. But they should come with the caveat that it's very early in the game.



doesn't. In these cases the result is there but you have really explored and data-dredged to get to it.

This has been described as "torturing the data until it confesses". What drives this?

Under the current reward system you get credit for publishing, for getting grants, for being the first – no matter how credible the work. Real innovation is important, but it is also extremely rare. Science is a communal enterprise. People don't operate in a vacuum and just wake up one morning with an idea that no one else had.

We need to realign our incentives to reward good quality, replicable research and sharing practices instead of how many papers you publish with how many extravagant claims.

"We don't need to apologise for science, but we should not claim more than we can"

Is that kind of systemic change possible?

It's not impossible. And I'm optimistic because I have already seen changes in several fields.

Scientists have good intentions. We are trying to get to the truth. That's what we want. At the same time we are under pressure from funding agencies and competition to come up with extreme results. So the main challenge is how to align the important stakeholders – not just scientists but funding agencies, journals, universities and research institutions. We don't need to apologise for science, it is the most wonderful endeavour, but we shouldn't try to claim more than we can.

What role do the media play in all of this?

You amplify signals. That means you can play a pivotal role if you disseminate credible information, show how difficult science is and help to teach the public what it means to have strong evidence, when to be cautious and that there are limitations in scientific work.

A lot of research never sees the light of day, particularly if the results are negative. Does this skew our understanding?

We know that for even the most visible type of research – clinical trials – about half aren't published. Even when they are, and the outcomes are also published, many aren't analysed in the way that was originally intended. A big problem is that investigators don't want to write up negative results, so they often write them up in a way that makes them seem to be positive. For other types of research, it may be even worse.

How do you spin a negative result as a positive one? Isn't that borderline fraudulent?

Oh, there are many ways. You can change the analysis so even though your intention was to compare A with B, you compare A with C. Or you follow up after six months instead of nine. Or you use a different scale, or some subscale of that scale. It's endless.

This isn't rare. About 75 per cent of scientists use these questionable research practices. They are distinct from fraud, though. Fraud is when you present a result that clearly isn't there, or say data exists that

How would you feel if you were wrong – if someone found problems in your own work?

Totally wonderful. I love finding that there's something that could be improved. This is what keeps me alive. I think that science is an evolutionary process where people find out that something can be done in a better way. Working on the science of science has exactly the same rules as any other field. So I'm very open to criticism – it can be very productive. ■

Interview by Douglas Heaven

Quantum computing

From Colin Williams, D-Wave

The world of quantum computing is complex, and while we appreciate Michael Brooks educating audiences on the various efforts, there were some misconceptions made about the D-Wave system in his article (18 October, p 43).

In particular, the article's table "Which quantum computer is right for you?" indicates that the D-Wave machine is only suitable for optimisation – finding the best solution to a given problem – and cannot perform other computations such as integer factorisation.

In fact, our machine has been used to perform optimisation, sampling, machine learning and constraint satisfaction. Although our machine cannot run Shor's algorithm, it has factorised integers tens of thousands of times larger than the integers factored by any other quantum computer currently available.

We were also given the lowest score on your "quantumness" category despite the fact that we recently published a peer reviewed paper (*Physical Review X*, doi.org/w46) demonstrating a world record for the number of superconducting qubits entangled. It was said that we cannot perform error correction, when, in fact, we can.

Finally, suggesting that the other quantum computers are all "easier to use" than our computer is a significant stretch. Our machines come with an interface that allows them to be programmed in Python, MATLAB, or C++ from any internet-connected computer in the world, and our users have harnessed this interface to demonstrate by far the widest range of applications yet achieved on any type of quantum computer.

Although quantum computing is still in its infancy, D-Wave has been a leader in the field, driving forward innovation on a scale that

most said was impossible. Our technology is being used by commercial customers today – something that cannot be said about any of the other efforts reflected on in the article. Vancouver, Canada

No benefit added

From Hugh Boyd

In support of harmonising regulations between the US and Europe through the Transatlantic Trade and Investment Partnership (TTIP), designed to break down barriers to trade, Tracey Brown asks who would defend a return to the wasteful delays of countries running separate clinical drug trials to meet local regulations. (1 November, p 33)

I for one would certainly defend separate clinical trials for statutory approval as well as for better understanding of new pharmaceutical products, given the bias which inevitably enters into these trials.

This wariness of bias is echoed by Iain Chalmers, one of the founders of the Cochrane Foundation, who in 2013 cautioned in the *BMJ*: "There is clear and consistent evidence of under-reporting and manipulation of the scientific literature by the drug and devices industries, and industry sponsors most of the world's clinical trials" (doi.org/w3w). The goal is of course unbiased clinical trials. Bearsden, Glasgow, UK

From Angus Kelly

I thoroughly enjoyed reading Tracey Brown's thoughts on TTIP and regulatory cooperation. However, Brown says chemical regulators look at benefits and risks when making assessments.

The European Chemicals Agency is bound to similar requirement as the European Food Safety Authority and can only consider risk. Brussels, Belgium

Profit and laws

From Bryn Glover

John Middleton cites examples of private companies that sued national governments for loss of profits under agreements similar to the Transatlantic Trade and Investment Partnership (TTIP) (1 November, p 34).

The question that occurred to me as I read about the various instances was of enforceability. If a legal complaint should prove to be well founded and the case awarded to the company, exactly how would the court's judgment be enforced if the national government simply chose to ignore it?

Harrogate, North Yorkshire, UK

The editor writes:

It's a good question. Under existing trade agreements, arbitration procedures are enforced by the treaty itself and cases are heard and enforced by arbitration panels such as the World Bank's International Centre for Settlement of Investment Disputes. But nobody knows in the specific case of TTIP because negotiations are ongoing and conducted in private.

Fuelling growth?

From David Sanderson

Imagining a world without fossil fuels, Michael Le Page fails to mention that without them, there is no way modern intensive agriculture could have developed (18 October, p 34).

Think of diesel for tractors, combines and distribution trucks, electricity for cold stores, and petroleum-derived agrochemicals. Without those things, we could not have huge modern cities nor the world population we currently enjoy.

Quite how massive industrial farms and food production and distribution systems will be able to cut their carbon emissions by 80 per cent, I do not know. Most



of the documents on low-carbon farming I have seen recently had a picture of a conventional tractor on the front! Ideas, anyone? Oldham, Lancashire, UK

From Owen Mooney

Although we are blessed in New Zealand with an abundance of renewable resources, these are not enough for our country of just 4 million. I work at a large electricity company in New Zealand. Our energy portfolio is mostly hydroelectric and geothermal. But we also burn natural gas and the odd bit of coal.

Almost all "green energy" articles look towards renewable resources such as solar and wind. But electricity must be supplied to match the demand of each moment. Being unable to meet this demand would spell economic disaster.

On a cold, still winter's morning, wind and solar need to be backed up by a complementary source such as coal or gas. But nobody wants to own or run coal and gas generators if they can only make money out of them for a few hours on a few days.

This prompts the much-feared nuclear option. Not only are politicians afraid to mention it, but so are many in the scientific sphere, even though statistically it is probably the least lethal form of large-scale power generation.

In terms of safety, we are still using 1960s technologies for our nuclear plants. If the aviation industry was similarly "advanced", we would still be flying propeller aircraft.

There is a lot to do. Molten salt reactors have to be evaluated, and possibly built and tested. The thorium promise needs to be looked at. The terrible inefficiency of uranium and radioactive waste needs to be looked at.

However, the most immediate need is for people of intelligence to look honestly at the future, our economies and our energy-demand life cycles and bring facts into the public sphere.
Auckland, New Zealand

Hard to swallow

From E. H. Bristol

You report that banded stilts tracked by GPS tags were found to fly 2200 kilometres in two days (1 November, p 18). That's crazy. Did anyone sit down and calculate average velocities of these birds?
Foxboro, Massachusetts, US

Green graphene?

From Peter Leach

Katharine Sanderson sets out the wondrous potential of new 2D materials such as graphene (25 October, p 40). Like all good things, however, there may be a downside overlooked in the excitement of discovery.

A key property of graphene is its high strength and, presumably,



durability. So what are the likely consequences of a world suddenly awash with stuff made from these new materials? I trust that, this time, someone considers the

recyclability and end-of-life issues for each new material before it becomes a problem and not afterwards. But I'm not holding my breath.

Mold, Clwyd, UK

Against the herd

From Perry Bebbington

Regarding the 2008 global market crash, the Queen may well have asked "why did nobody notice it?" (1 November, p 28). But she was wrong, some people did.

Many were laughed at and some quietly got ready for it. Gregory Zuckerman's book *The Greatest Trade Ever* gives a wonderful account of how John Paulson saw it coming and made \$20 billion betting against the markets.

It is not in the interests of people who see crashes coming to say anything, because they are either ridiculed, or in the case of people like Paulson, stand to gain a great deal of money if their predictions pay off.

Kimberley, Nottinghamshire, UK

Dark side of research

From Adrian Ellis

In your article on decoding brain signals (1 November, p 8), the scientists report that they have followed their work on reading these impulses by "turning their hand to predicting what songs a person is listening to by playing lots of Pink Floyd to volunteers". Is this ethical?

Hampton, Middlesex, UK

Moral code

From Stephan Györy

In Jacob Aron's article on hybrid computers, Chris Eliasmith says that neural networks are required "if you want to build a computer that is cognitive in the way we are" (1 November, p 21).

But do we? I'm with Elon Musk

in thinking that fundamental questions like this need to be asked and the answers debated before we go too far down this road.

Humans with different belief systems are bad enough at getting on with each other, especially with the limited resources our little globe can provide. Throwing a naive but globally networked "alien" awareness into the mix will have unintended consequences. What belief system will it be programmed with? At



the very least we need a robust, internationally agreed framework within which to move forward.

Darlinghurst, New South Wales, Australia

Full of beans

From Brian Wall

In her guide to the human mind, Caroline Williams recommends caffeine to shake off sleep inertia in the mornings (4 October, p 34).

This advice is worthless as any studies supporting her contention were inevitably carried out on caffeine addicts. I gave up caffeine 26 years ago and I am fully awake every morning if I go to bed early enough. Caffeine is a useless and damaging addition to human life. Like all recreational drugs, the only people who need them are those who take them.

New Scientist should not promote addiction to anything, and especially something that tastes so disgusting. It's time to get the drugs out of our system.
Glengarriff, Cork, Ireland

Smoke signals

From Brian Smith

It's easy to find out if e-cigarettes help you quit or get you hooked (1 November, p 35). Just ask the tobacco companies if they are for or against them.
Berlin, Germany

Don't panic

From John Barnard

I was fascinated by Michael Slezak's article describing a new take on the many worlds theory for explaining quantum mechanics (8 November, p 6), particularly as the theory predicts that as few as 41 other universes existing alongside ours could explain these effects. Is it possible that the answer to "Life, the Universe and Everything" is 42, as Douglas Adams knew all along?
Verwood, Dorset, UK

■ *The editor writes:*

The universe modelled by Howard Wiseman and his colleagues uses 41 worlds including ours. But that was the minimum number needed to get a qualitatively similar result to the double-slit experiment, so 42 would work too.

For the record

■ Our claim about a burst water main near Singapore's Marina Bay Sands didn't hold water; the leak was several hundred metres away and was spotted before it could threaten the complex (8 November, p 20).

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Us versus The Universe

Who said the laws of physics are immutable? Anil Ananthaswamy and Jacob Aron set out to bend the rules

OK, SO no one said understanding the cosmos was easy. Try as we might to understand natural phenomena, we often run smack bang into limits set by the laws of physics. Does that put us off? Not a bit of it. Using our smarts, we can bend some laws or even use one law to sneak around another. Take that, universe! Read on to find out more...

gravitational waves, which are a key unverified prediction of Einstein's general theory of relativity. Experiments to detect these ripples in space-time rely on measuring tiny disturbances to laser light bouncing between distant mirrors. "People believed there was a fundamental limit for the sensitivity of such detectors, the standard quantum limit," says Karsten Danzmann of the Max Planck Institute for Gravitational Physics in Hanover, Germany, who works on one such detector, GEO 600.

In fact there is a loophole. Uncertainty says you can learn more about one quantity by knowing less about its complementary quantity. To detect high-frequency gravitational waves, you need to know accurately the number of photons hitting the mirrors, but are less concerned about its complementary quantity, their arrival times. Squeeze all the uncertainty into the photons' timing, and you can increase your detection-sensitivity dramatically.

"Squeezed light" was first proposed by physicist Carlton Caves in the 1980s, but it is only in the past decade that physicists mastered the necessary techniques, which involve splitting one normal photon into two with squeezed uncertainty. GEO 600 now uses the technique routinely - and there seems to be no limit in sight. "Squeezing will improve, slowly, but steadily," says Danzmann.

SQUEEZED KNOWLEDGE

Heisenberg's quantum uncertainty principle

IN FEBRUARY 1927, a young assistant to the quantum pioneer Niels Bohr had a brainwave about why measuring electrons provided consistently fuzzy answers. "The more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa," he wrote.

Werner Heisenberg had discovered his famous uncertainty principle - a cornerstone of quantum physics that limits how well we can know not just position and momentum, but a whole host of "complementary" pairs of quantities.

Uncertainty has practical consequences. Take



DAN MATUTINA

A SHINING EXAMPLE

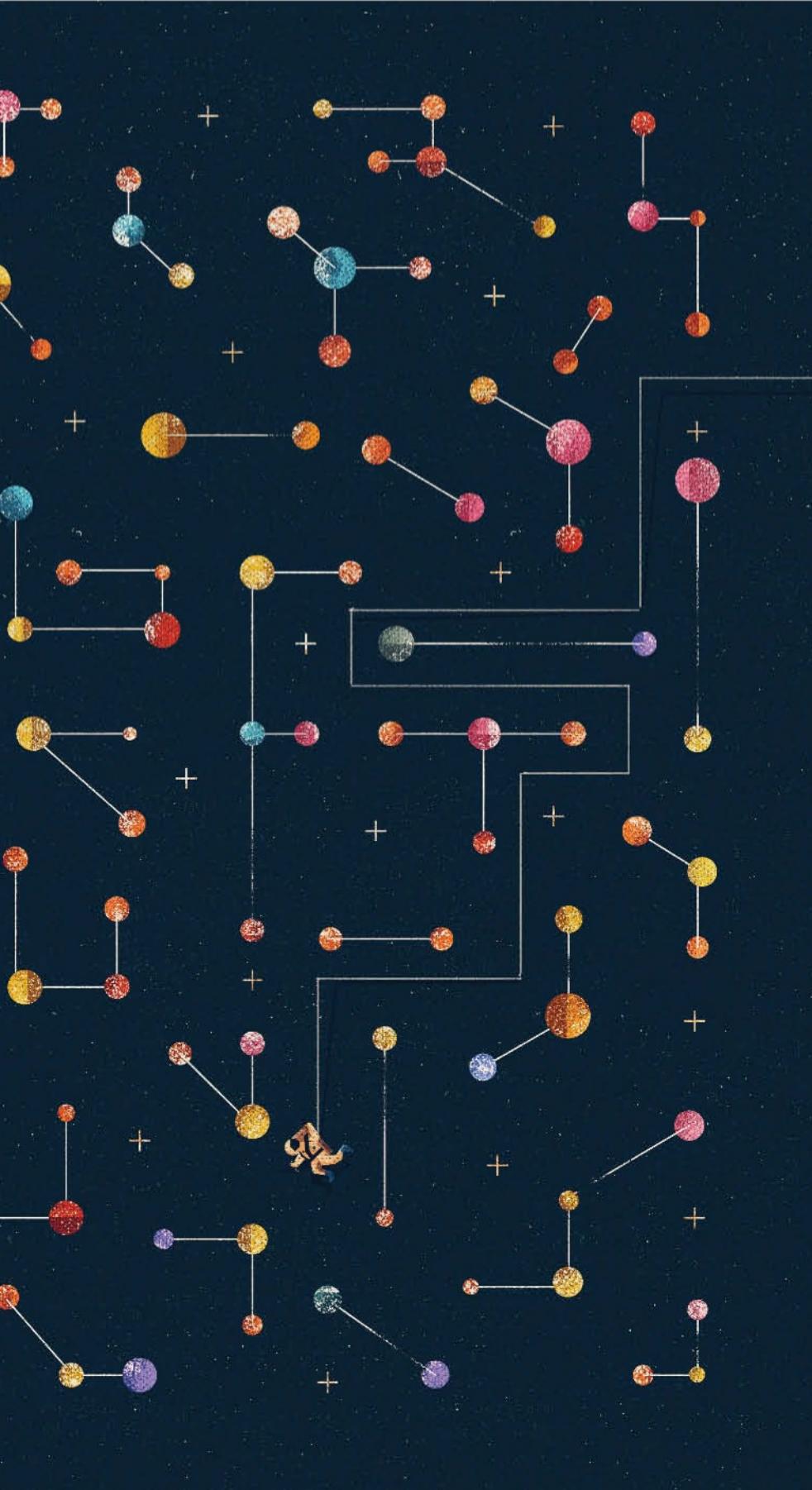
Diffract limit



TALK about microscopes and you bump up against the diffraction limit. Traditional microscopes cannot see objects smaller than about half the wavelength of light, because of how light bends and scatters at the edges of lenses. The limit equates to about 200 nanometres for visible light. "This has been impeding light microscopy throughout the 20th century," says Stefan Hell of the Max Planck Institute for Biophysical Chemistry in Göttingen, Germany.

Hell won this year's Nobel prize in chemistry for his part in overcoming this problem. He pioneered an ingenious technique called stimulated emission depletion microscopy, whose basis is shining a beam of light at stained biological tissue so that the illuminated part fluoresces. Because of diffraction, the smallest this spotlight can be is 200 nanometres. Hell's workaround is to add a second beam made so that its spot of light is dark at the centre. When the second beam is perfectly aligned with the first, it partially cancels the sample's fluorescence, leaving only the part corresponding to its dark patch fluorescing. This patch can be made much smaller than 200 nanometres, allowing what was previously thought impossible - the imaging of individual molecules. "The diffraction barrier has definitely been overcome," says Hell.

There is another way to dodge the diffraction limit. A class of engineered "metamaterials" have properties not found in nature and can bend light the opposite way. Superlenses made from metamaterials have smashed the diffraction limit.



LESS THAN NOTHING

Absolute zero

DEFINING a temperature scale is easy. Fire is hot, ice is cold, draw a line between the two and there you are.

But what makes fire hotter than ice? The 19th-century physicist William Thomson, later Lord Kelvin, gave one answer. He defined temperature in terms of kinetic energy. In hot bodies, particles are moving around a lot; in cold ones, not so much.

Kelvin's scale implied a natural lowest temperature at which particles stop moving completely. It is impossible even to make something reach this "absolute zero", since that would imply the existence of

>

something even colder to cool it with – let alone leap to negative temperatures beyond it.

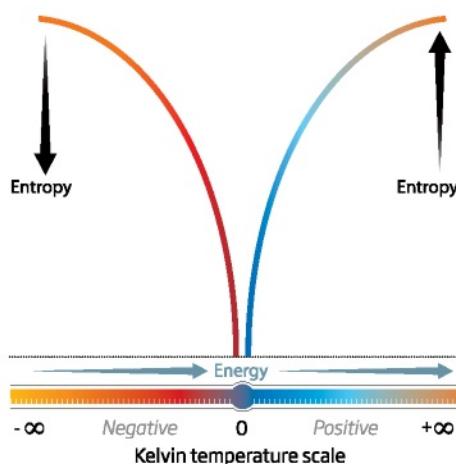
Or is it? It turned out later that temperature depends not just on particle energies, but how that energy is distributed: disorder, or entropy. Increasing entropy also implies heat flow – and temperature change. Because of the way Kelvin defined his scale, increasing a system's energy while reducing its entropy registers as a negative temperature. In fact, there is a whole mirror world of negative temperatures stretching towards absolute zero from negative infinity (see diagram, right).

Motion and disorder usually increase in lockstep, so states of increasing energy and decreasing entropy are not things we stumble across every day. But physicists can make them. Most recently a team led by Ulrich Schneider of the Ludwig Maximilian University of Munich in Germany created a negative-temperature state by using lasers to manipulate atoms cooled to a fraction above absolute zero.

It's a bit of a cheat, really. Absolute zero still represents the lowest energy a system can have; it's just that Kelvin's scale doesn't necessarily reflect that. Those in the know prefer to speak of negative thermodynamic beta, which assigns the value of minus infinity to absolute zero and climbs smoothly upwards with increasing energy. Or maybe we should just stick to Celsius.

Wrong way round

Conventional, positive temperatures rely on energy and entropy both increasing. But when entropy decreases things can get even hotter – although these temperatures register as negative on the Kelvin scale



TAKING OUT THE TWINKLES

Atmospheric limit

BUILD an 8-metre-wide telescope high up in the spectacularly clear Chilean Andes and it will see no better than a space telescope just 50 centimetres across. That's because of Earth's pesky atmosphere. Variations in temperature and pressure in the atmosphere's layers cause starlight to zigzag as it travels through. What to us is pretty twinkling makes for blurry images that limit observations.

We can't make the atmosphere any clearer, but there is a way around its limits. Shooting a laser into the night sky lights up a layer of sodium atoms 90 kilometres up, at the outer edge of the atmosphere. This creates an artificial guide star. Astronomers know exactly what it should look like without any atmospheric turbulence, so they can use the extent of blurring recorded by the telescope

to figure out how starlight has been affected. They use this information to rapidly move a small, deformable mirror in the telescope's eye view to cancel the atmospheric blurring.

One of the most sophisticated of these adaptive optics systems was recently installed in the 8-metre Gemini South telescope, atop Cerro Pachón in Chile. It uses five guide stars and three mirrors that change shape a thousand times a second. "In a given image, you get 10 to 20 times more information," says Benoit Neichel at the Gemini South Observatory in La Serena, Chile.

Guiding light: shooting lasers into the sky allows astronomers to cancel out atmospheric effects

OUT OF THIS WORLD

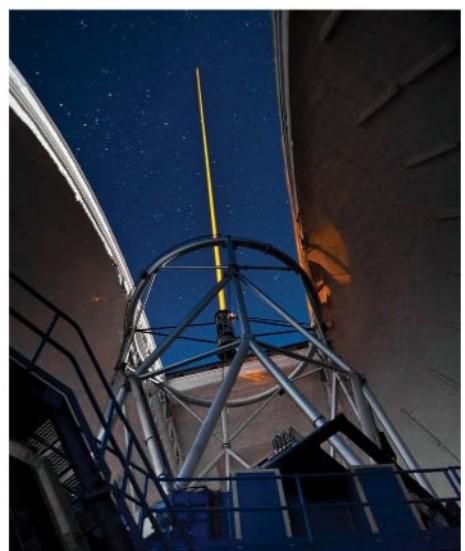
Seismic limit

DETECTING ripples in space-time is, on paper, easy: you simply measure how passing gravitational waves disturb the transmission of laser beams bouncing between mirrors. The devil is in the detail, though. Because the disturbances are unbelievably tiny, physicists have had to invent all sorts of clever tricks in their efforts to detect them (see "Squeezed knowledge", page 36).

One limit looks impossible to dodge here on Earth, however: the seismic limit. Seismic motion from earthquakes around the world shakes the mirrors, causing noise that can overwhelm any signal. The mirrors can be shielded from most tremors, but ones below 1 hertz are trickier to cancel out. This quashes hopes of finding low-frequency gravitational waves emitted by pairs of dense stars, or stars captured by supermassive black holes. "That is probably a fundamental limit for the low-frequency sensitivity of any ground-based detector," says Karsten Danzmann of the Max Planck Institute for Gravitational Physics in Hanover, Germany.

The way around this limit is to fly your detector in space. The European Space Agency's eLISA mission is scheduled to fly in 2034. eLISA is three satellites flying in a triangle formation around the sun.

Each satellite will fire laser beams at the others to precisely measure the distance and spot any telltale stretch-and-squash of space-time caused by a gravitational wave. Each side of the triangle will be a whopping 1 million kilometres long, which opens up the possibility of detecting gravitational waves we would never spot on Earth. "Any supermassive black hole coalescence, wherever and whenever it occurred in the universe, will be detectable with eLISA," says Danzmann.



SIGNATURES OF THE INVISIBLE

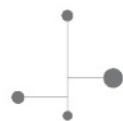
Cosmic limit

IT'S the universe's first light. The cosmic microwave background (CMB) formed about 380,000 years after the big bang, when the fog of the early universe cleared enough for light to travel unimpeded through the cosmos. We cannot see beyond this curtain of light to earlier times. It's the limit of our electromagnetic vision.

But not of all vision. Like footprints on an empty beach, imprints on the CMB tell the story of what happened before. Today we see the light, stretched in wavelength due to the expansion of the universe, as microwaves in the sky.

These microwaves have a temperature of 2.726 kelvin. In a technical tour de force, NASA's WMAP satellite was built to map variations in this temperature as small as 1 part in 100,000, across the entire sky. This revealed that the early universe contained relatively denser regions, which would become seeds for clusters and super-clusters of galaxies.

Events that happened even earlier,



when the universe was just 10^{-36} seconds old, are also thought to have left their mark. This is when the universe supposedly underwent a period of blistering expansion called inflation, sending ripples through space-time that polarised the light in a characteristic pattern. Earlier this year the BICEP2 telescope at the South Pole controversially claimed to have seen this faint signature, but the European Space Agency's Planck satellite has yet to confirm the findings.

On Earth, the Large Hadron Collider at CERN, near Geneva, Switzerland, is also helping smash the cosmic limit - by showing us what the universe might have been like just microseconds after the big bang. The LHC does this by colliding lead ions accelerated to near light speed. The collision creates energies so high, at temperatures of about 5.5 million kelvin, that all matter disintegrates into its constituent quarks and gluons - a mini big bang whose quark-gluon soup is now being analysed.



ROBERT SCHWARTZ, UNIVERSITY OF MINNESOTA



IT'S NOT JUST A GOOD IDEA, IT'S THE LAW

Speed of light

THIS T-shirt slogan has its basis in Einstein's equations of special relativity, but obscures a subtle fact. "Conceptually, special relativity does not imply that nothing can travel faster than light," says theoretical physicist Abhay Ashtekar at Penn State University.

It says that if a particle is moving slower than the speed of light, c, only an infinite amount of energy will accelerate it above c. And if a particle is moving faster than c, you cannot slow it down to below c.

Some phenomena seem to violate this speed limit. Cosmic rays zipping through water create the optical equivalent of a sonic boom, implying they are going faster than light speed. But the rays are only exceeding the speed of light in water, not the speed of light in a vacuum - the ultimate barrier.

Galaxies at the edge of the universe are also moving away from us faster than the speed of light. However, this is due to the ongoing expansion of the universe, which is not really a velocity in the strict sense.

Something similar is true for quantum-entangled particles. When you measure one of a pair - no matter how far apart they are in the universe - you immediately influence the other. This seems to be faster-than-light signalling, but if you try to use entangled particles to exchange information, you are again limited by the speed of light.

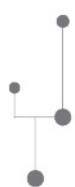
So while we've had a good ride breaking other physical laws it seems nothing - not particles, not information - can break the universe's speed limit. ■

WHY THINGS MATTER

Pauli exclusion principle

DESPITE its name, this principle is pretty inclusive: it makes all normal matter what it is. Named after the Austrian physicist Wolfgang Pauli, who proposed it in 1925, it says that no two electrons in an atom can enter the same quantum state. This leads to atomic electrons filling an elaborate structure of higher and higher energies around the nucleus, explaining why atoms with different numbers of electrons have different properties. Without the Pauli exclusion principle, the chemical elements wouldn't exist.

The principle applies not just to electrons, but to all the particles that make up conventional matter, collectively known as fermions. Its influence extends even to the stars. Very dense cosmic bodies such as white dwarf and neutron stars resist collapsing in under their own immense gravity because the Pauli exclusion principle prevents electrons and neutrons from crowding together. In the case of white dwarfs, this holds until the body reaches a certain mass, when the force of gravity becomes overwhelming and the star explodes as a supernova. This mass



was first calculated by the Indian-American astrophysicist Subrahmanyan Chandrasekhar to be 1.4 solar masses, but has recently been observed to be even higher in some cases (*New Scientist*, 27 July 2013, p 46).

It all sounds pretty cast-iron. But as Deborah Jin of the University of Colorado and her colleagues found out in 2003, you can circumvent Pauli's principle - although only at low, low temperatures. When it's that cold, particles behave differently, and fermions can be encouraged to pair up. These paired particles dance to a very different tune, and the Pauli exclusion principle ceases to apply, enabling groups of them to all enter the same quantum state.

Jin's first creation of a "fermionic condensate" involved potassium-40 atoms, which act like very big fermions, cooled to within a whisker of absolute zero and nudged to pair up in a magnetic field. "In some ways you are getting around the Pauli exclusion principle," Jin says. Only in some ways: fermions on their own are still subject to its iron rule.

Anil Ananthaswamy is a consultant for *New Scientist* and Jacob Aron is *New Scientist's* physical sciences news reporter



Hear yourself happy

Want to feel instantly lively, slimmer, or more motivated? Try tweaking the noises your body makes. Corrinne Burns tunes in

AS a rule, I don't remove my shoes in public. But today I'm making an exception. Surrounded by engineers and psychologists, I pull off my Converse and step into a pair of rather ordinary-looking brown leather sandals.

I begin to walk slowly around the room, and that's when I experience the most peculiar sensations. The sound of my footsteps changes, and suddenly my lower legs feel lighter and longer. My knees feel looser, and I begin to raise them higher and higher as I walk. My walking speed increases until it's all I can do not to break into a trot. I feel slimmer, stronger, and full of energy. These are unlike any shoes I have ever worn.

Such footwear sounds fantastical, but these shoes are just one of a number of new experiments revealing how the noises we

make have an immediate and profound effect on the way we experience our bodies, on our emotions and our behaviour. The trick here is not in the shoes themselves, but in the way they change the sound of my footsteps.

This phenomenon raises the tantalising prospect that simply donning a particular pair of shoes or a headset could help us feel energised, more inclined to exercise – or just happier.

The discovery also sheds light on the way the brain builds your sense of self. This could have big implications for people who struggle with how it feels to live inside their bodies, not least those with chronic pain or psychological problems with their body image.

The sensation of inhabiting our own body is so familiar we barely give it a second thought. But over the last decade it has become clear

ANDREW LYONS



what a complex construction this feeling is.

Much of what we know about it comes from studying the brain circuits of people subjected to the rubber hand illusion – one of the most well-established experiments into our sense of embodiment. In the classic version, a rubber hand is placed on a table in front of a volunteer, in a natural-looking position, and the person's own hand is hidden from their view. Then they see the rubber hand being stroked, while their real hand is simultaneously stroked in the same way. The experience results in the person perceiving that the fake hand is their actual hand.

These experiments suggest that we carry a mental model of our body – how many limbs we have, for example, and where they are in relation to one another. This model is then constantly updated with sensory information from the outside world, and from special receptors inside the body that sense the movement and position of joints and muscles – called proprioceptors. In the case of the rubber hand, it is the combined visual and tactile input that convinces the volunteer's brain that the hand is in fact part of their body.

We now know that much of this integration happens in an area of the brain called the right temporoparietal junction. This area collects

and processes information about body movement, and sensory information such as sight, touch and sound.

When it is disrupted using magnetic stimulation, people suddenly find it hard to figure out where their body ends and the outside world begins.

Variations of the rubber hand illusion have since shown that as long as enough information from different senses reaches the brain, it is surprisingly easy to change what people feel to be the limits of their physical form. With a bit of technology, it is even possible to fool someone into perceiving an entire other body as their own.

Personal soundtrack

These perception-skewing studies have so far relied on vision, touch and proprioception to understand the way in which the brain constructs this sense of an embodied self. Until now, the role of one sense had been widely overlooked. "Sound is a fundamental yet under-investigated dimension of body representations," says psychologist Manos Tsakiris at Royal Holloway, University of London, who has conducted much of the embodiment research. "For hearing people,

there is a continuous, ever-present soundtrack to our bodily actions."

We use this soundtrack to infer information about other people: just hearing someone's footsteps hints at their size, for example. Ana Tajadura-Jiménez, who studies perception at University College London, is now focusing on the sounds we make ourselves. "What do they tell us about our own bodies?" she asks.

In trying to answer this question, she is finding that hacking our hearing can have profound and surprising effects. In an early experiment, Tajadura-Jiménez's team at UCL's Hearing Body Project asked a group of volunteers to do a trial that involved tapping a desk while speakers played the sound of the taps at increasing distances. After each trial, participants were subjected to a touch test on each arm (see illustration, page 43).

When the sound originated from double the distance away from the tapping, a curious phenomenon occurred – the volunteers significantly overestimated the distance between two touch points on the tapping arm. Their brain perceived that arm to be longer, even though they weren't consciously aware of it having stretched (*Current Biology*, DOI: 10.1016/j.cub.2012.04.028).

In a similar experiment, blindfolded ➤

volunteers were asked to drop a ball, which was surreptitiously caught in a net. Instead of the true sound of the ball hitting the floor, a recording was played, with a varying time lag. Similarly to the arm experiment, the longer the lag, the longer they felt their legs to be.

Tajadura-Jiménez suspected that manipulating the audio feedback in this way disrupts the brain's internal model of the body by causing a mismatch between the input it gets from the different senses. Strange bodily sensations result, as the brain tries to account for the discrepancies.

These kinds of manipulations not only alter how we perceive the body, but can also affect behaviour. Touching surfaces generates sounds, however subtle. In another test, blindfolded volunteers stroked a smooth plastic board, but through a headset heard the sound of touching either sandpaper or velvet.

The sound they heard affected their actions – participants became hesitant to stroke the board when they heard sandpaper, but not when they heard velvet. (To experience this for yourself see the online version of this story here: bit.ly/NSsoundFX)

Slimming shoes

Tajadura-Jiménez now wants to know if it is possible to harness these peculiar experiences in more profound ways. This is why I find myself standing in my socks. A part of her team's most elaborate experiment yet, I am handed a pair of sandals fitted with microphones linked to a set of earphones. I don the shoes, put the earphones in, and begin to walk on the vinyl floor.

It is an unnerving experience. At first, I simply hear the unmodified sound of my footsteps. But then Tajadura-Jiménez filters the noise using an equaliser. Emphasising the higher frequencies mimics a lighter person's footsteps, causing them to sound higher-pitched, even slightly hollow. In a matter of seconds, I experience a sensation of lightness in my lower legs. And that's when I start to feel the other changes in my body too. The opposite effect also occurs – lower frequencies cause people to drag their feet like a heavier person.

What's going on? Tajadura-Jiménez thinks that what I experience is a conflict between two senses: hearing and proprioception. My brain, quite rightly, expects my body to be 156 centimetres tall and weigh about 55 kilograms. But thanks to the get-up, my ears pick up the sound of a considerably lighter person – and my brain updates my body representation



ELLIOTT ERWITT/MAGNUM PHOTOS

Tongue trick

As with sound, taste manipulations can have surprising effects on the way we experience the world.

Earlier this year, a team at the University of Oxford's Crossmodal Research Laboratory asked volunteers to stick their tongue through a hole in the side of a box, which was equipped with a strategically placed mirror. This made them see a fake, rubber tongue in place of their own.

Participants then watched as a cotton bud was stroked along the fake tongue while the same thing happened to their tongue. Seventy per cent of them perceived the fake tongue to be theirs.

Next, the volunteers saw a cotton bud get dipped in lemon juice and applied to the rubber tongue, while a water-soaked bud was simultaneously applied to their own. To the researchers' surprise, a few participants reported a sour taste.

"It's the first time that vision has been shown to influence perception of an internal organ," says study co-author Charles Michel.

We already know that how food looks affects how much we like it. If we can make people perceive taste on a virtual representation of their tongue, Michel says, it raises an interesting question: "How much of our everyday experience of food is an illusion?"

You don't need to be in love to get an added spring in your step

accordingly, putting an added spring in my step.

This idea fits with a fairly recent theory of how the brain works, called predictive coding. This depicts the brain not as a passive recipient of sensory information but a complex prediction machine, which makes sense of the world by forecasting the probability of various events occurring.

Those predictions are based on prior experience, but they are continually updated. This way of calculating how likely something is to happen is known as Bayesian statistics. The Bayesian model of the brain explains how we can instinctively work out, for instance, whether there is time to cross the road in front of an approaching car – we make a prediction based on past experiences, but the brain will update that calculation if new information comes in, such as the car suddenly accelerating.

Predictive coding is a compelling explanation of how these experiments work their magic. "If the sensory feedback you get is not what you were expecting, you update your predictions," says Tajadura-Jiménez. My brain predicted that my footsteps would sound the way that they usually do. These shoes, though,

provided unexpected sensory information, and so my brain quickly “corrected” its error, creating an illusion of lightness.

Tapping into these expectations could affect much more than the way we walk. Tajadura-Jiménez says people who try the shoes often report feeling happier. What’s more, when participants are asked to adjust the size of a virtual avatar to reflect their body shape, after walking in the shoes, they consistently depict their virtual selves as slimmer than before.

The effects are temporary – it only takes a few seconds without the shoes to return the wearer to their original state. Still, such footwear could be just the ticket for anyone in need of an instant confidence boost.

Could they also help people with serious issues with their body image? Tajadura-Jiménez is now teaming up with medics interested in how sound manipulations could help people with body dysmorphia to adjust their distorted body image. “We are finding that sound is affecting not just the perception of our body shape but our physical

“Manipulating sounds changes the size people feel their waist to be”

capabilities,” she says. “Understand these sounds, and we could change our feelings in a positive way.”

There’s reason to think this group could be particularly responsive to interventions with sound and touch. People with eating disorders have already been shown to be more susceptible to tricks like the rubber hand illusion. And in as-yet-unpublished research, Tajadura-Jiménez’s team has found that experimental sound manipulations can change the size volunteers feel their waist to be. People who were more concerned about their body shape felt the illusion more strongly.

These experiments suggest that you could consider body dysmorphia to be a disrupted sense of embodiment, says Anil Seth, who studies consciousness and identity at the University of Sussex in Brighton, UK – and that it might well be amenable to treatment with some of these new approaches.

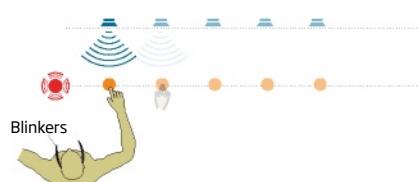
The findings clearly run deeper than the contours of the body – perhaps even to our fundamental sense of identity, he says. “I believe that our sense of self is at least partly determined by the brain’s inferences about

Arm stretching illusion

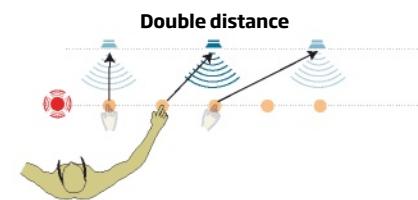
Manipulating sounds can trick your brain into thinking your limbs are longer than they are

A person taps a point (●) 10 times with their right hand in time with a flashing LED, and a hidden speaker amplifies the sound. Without leaving their seat, they repeat the taps at each point

Hidden speaker location matches tap location



In the next trial, the speakers are placed at double the distance between the person and each tapping point. Before and after each trial participants were touched in two places simultaneously on their right arm and on their left



When the tapping sounds originated from **double the distance**, participants perceived the touches on their right arm to be significantly further apart than they really were

Their brain perceived the right arm to be longer



When the speakers were further away the illusion was broken

the shape and physiological conditions of what it considers to be its body.”

So, change the shape, change the person? Work by Amy Cuddy of Harvard Business School and her colleagues shows that simply getting people to change their posture – even if they don’t realise they have done so – can make them feel more powerful and, in turn, more likely to take risks. For instance, her team found that people who drive cars whose seats are designed to encourage a more expansive driving posture were more likely to park illegally.

In other experiments, when adults wearing

a virtual reality headset were made to inhabit the body of a child, they started to identify more with childlike qualities in themselves, rather than adult ones.

This is an idea known as embodied cognition, whereby the way our body looks, feels and moves influences the way we think and behave. Tajadura-Jiménez plans to investigate whether her sound manipulations could be used to trigger similar responses, changing the way people think about themselves more fundamentally.

In the meantime she is focusing on people with chronic pain. Feeling pain in one part of the body often leads to distortions in a person’s sense of movement and positioning, leading to reduced awareness of their actual movement. For example, they tend to think their body is stretching more than it really is, and this makes it hard to carry out physiotherapy exercises. Some of their proprioceptors also switch to transmitting pain.

Tajadura-Jiménez and colleagues at UCL’s Emotion and Pain Project and at the University of Genoa in Italy have developed an app which works as a kind of sensory prosthesis, giving people with chronic pain real-time information about their body movement and location. The hope is that it will help them to stretch further, and will reset their proprioceptors to accurately represent their body position. This might give them a better idea of their true physical capabilities and stop the proprioceptors from transmitting pain.

Another app, which would allow people to modify the sounds their footsteps make is also in development, Tajadura-Jiménez says. The idea is that anyone could get the benefits of her sandals, “when walking or running, perhaps in the gym, to feel lighter and more motivated”.

This is the kind of thing that should appeal to makers of sports equipment, says sports engineer Steve Haake at Sheffield Hallam University, UK. “Something that enhances runners’ perception would be very popular.”

From my short time in Tajadura-Jiménez’s shoes, I would certainly agree. The feeling of lightness I experienced vanished as soon as I took them off, so I would be keen to have such a trick regularly at my disposal. The experience has also left me with a newfound appreciation of the role sounds play in forming my sense of identity. Walk a mile in these shoes, and you’ll never feel the same again. ■

Corrinne Burns is a freelance writer based in London



Brown is the new white

Can the snowshoe hare adapt its coat to diminishing snow cover, asks Lesley Evans Ogden

TIS midsummer in Montana. Traipsing through the lush, dewy forest undergrowth, the morning mist is lifting and shafts of orange sunlight beam through the trees. To nature's soundtrack of a gurgling stream and birdsong, we check for quarry in live traps near Seeley Lake in the Rocky mountains. From the third one we visit, a young snowshoe hare stares up at us, silent, its whiskered nose twitching. This juvenile has unwittingly signed itself up for a cross-continental journey for science.

The snowshoe hare is one of 11 species worldwide that turns pure white in winter. The regrowth of its brown summer pelt has evolved to synchronise with average snowmelt times – dates that have been relatively stable for centuries. Not any more. In temperate regions, periods of snow cover are getting shorter – one of the strongest signals of climate change. Snowmelt times are changing so quickly that hares are being caught out of fashion – staying white when their snowy background has already melted. This young hare will be transported across the country to North Carolina State University, where it will help my companion Marketa Zimova and her colleagues answer an important question: can the snowshoe hare adapt to shifting climate?

Scientists have long been intrigued by animal camouflage. The story of the peppered moth is a classic example of how background matching can, through natural selection, track human-imposed habitat changes. Before the industrial revolution, the vast majority of peppered moths were pale coloured, like the trees and lichen they rested on. Within 50 years, the darker-winged ones had become more prevalent as this provided better camouflage on the soot-covered trees.

However, early investigations into camouflage were often flawed because researchers based their work on their own vision, says Sami Merilaita at Åbo Akademi University in Finland. What's important, he says, is how the animals' predators see.

The snowshoe hare is the primary prey of the lynx and forms part of the diet of a host of other mammals and birds. Avian predators have good colour vision but mammals do not. "Mammals have dichromatic vision, like colour-blind people," says Merilaita. "They can't distinguish between green and orange very well, and probably green and brown as well." So, while speedy hops help snowshoe hares evade some predators, for others its camouflage is vital.

But hares have other interests, such as



Unlike hares, male rock ptarmigan know they stand out and use this to attract mates

finding food and mates, and these "may conflict with the need to maximise their background matching", says Merilaita. In fact, some species that turn white in winter appear to delay the change back on purpose.

Arctic-dwelling rock ptarmigan have a white winter plumage and a mottled brown summer plumage. As snow melts in spring, females quickly moult and change colour, but males take almost a month to do so. Not surprisingly, the males experience higher mortality than females during this period.

Clues about why ptarmigan remain dangerously white have emerged from a 17-year field study by Bob Montgomerie at Queen's University in Ontario, Canada, and his team. Their observations suggest that the males flaunt their stark whiteness to woo females. Then, when hens are no longer fertile, the cocks deliberately soil their plumage with mud until they moult.

In an attempt to test this idea, the researchers dirtied the feathers of male ptarmigans in the mating season with a black "indelible" marker. It took the birds just 48 hours to completely remove the ink, says Montgomerie. "It was a strong clue that staying white was important, and that the birds were actively keeping themselves as clean as possible."

Hare-brained

By contrast, snowshoe hares appear to be oblivious to whether or not they are camouflaged. "They do not act in any way to reduce colour mismatch, or to reduce the negative consequences of mismatch," says Zimova. When mismatched with their environment, they don't hide more, flee more or hang out in areas that match their

coat. In short, these hare-brained creatures don't seem very smart.

If they can't adapt their behaviour, can they at least shift the timing of their moults? Zimova and her colleagues recorded coat-colour change in wild hares over three Montana winters starting in 2010. Locating radio-tagged hares weekly and noting what proportion of the fur cover was white, they examined the length of time individuals were mismatched with their background – defined as a difference of at least 60 per cent between coat whiteness and snow cover. On average, this came in at nine days a year. And mismatched hares paid a price; they were 7 per cent less likely to survive the week to the next assessment than hares whose pelts matched their environment.

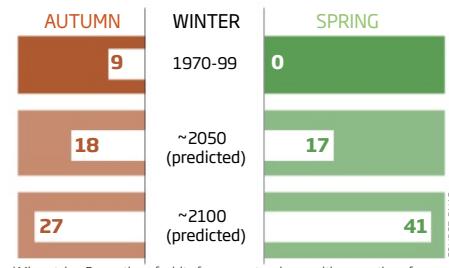
The study also revealed that the dates when moulting began in autumn and spring remained stable, despite large annual

Snowy mismatch

The snowshoe hare's coat changes from brown to white in autumn and back in spring to reflect varying snow cover. As climate change reduces the length of winter, it may be left wearing the wrong coat



Number of days of colour mismatch*



*Mismatch = Proportion of white fur cover at variance with proportion of snow cover by more than 60%

differences in snow duration. This suggests that the main trigger of moulting is the length of the day, not snow cover.

Other factors may also be involved. Looking closely at the two moulting seasons the team noticed that hares took about 40 days to change colour in autumn whatever the conditions. In spring, however, the rate of change was more flexible, with the moult lasting 16 days longer in the year with the longest period of snow cover compared with the shortest.

The source of this flexibility is unclear. Temperature and duration of snow cover appeared to have little effect in autumn. "[In spring] it might be the high reflectance of snow that enters the eye and triggers a hormonal cascade that slows down the change to brown," says Zimova.

The researchers can now test out their theories and investigate the genetics underpinning coat change at a futuristic-looking facility on the campus of North Carolina State University. In a series of stainless-steel-walled chambers, the young hare Zimova and I trapped, together with

"Snowshoe hares seem oblivious to whether or not they are camouflaged"

a dozen or so others, is being exposed to a variety of conditions to see how these influence the timing and length of moult. From a central control system, the researchers can manipulate day length, temperature and light conditions to mimic the reflectance of snow or bare ground – mechanisms that might drive the hares' twice-yearly wardrobe change.

The team calculates that if the snowshoe hare fails to adapt, by 2099, reduced snow duration will increase mismatch to between 39 and 68 days a year. Theoretically, that could drive the species to extinction. It is unlikely to come to that, however. Given that individuals vary widely in the timing of their moult, and that those with the wrong colour fur face an increased risk of death, natural selection is likely to kick in.

"There is large potential for adaptation through evolutionary change," says Zimova. So as long as some snowshoe hares can stay hidden as snow cover decreases, the species isn't doomed. Natural selection will favour quick changers. Evolution can hop to it. ■

Lesley Evans Ogden is a freelance writer based in Vancouver, Canada



RIVER OF THE DAMMED

Peter Hadfield travels down the Yangtze to see how it's being affected by the world's biggest dam

OUR Chinese guide waves a flag above his head and we follow him past manicured gardens and a delicate lady playing a four-stringed "pipa", until we reach a lookout point. Here, with the Three Gorges dam looming in the background, the gushing commentary continues.

"The dam is the largest in the world, built with 27 million cubic metres of concrete. It has the largest generating capacity in the world and the largest..."

I am distracted by the fact that we can't actually see much of the dam, thanks to China's notorious pollution. The 2-kilometre-long dam wall disappears into a cloud of smog. Somewhat fitting, given that our guide was telling only half the story anyway. This is the

biggest dam in the world, but it also has the biggest problems – from unexpectedly fast silt build-up to dam-triggered earthquakes and erosion far downstream.

A few years ago, the Chinese government openly acknowledged that there were "urgent problems" that need to be addressed. Since then, things have gone quiet. So I embarked on a 1500-kilometre journey down the Yangtze river to find out what is happening.

My journey started at the other end of this extremely long and thin reservoir, 600 kilometres away in the inland city of Chongqing (pronounced "Chong-ching"). Thanks to the dam, which got the go-ahead in 1992, tankers and cargo freighters can now travel all the way to this city. The increased

ship traffic has made Chongqing one of the fastest-growing cities in China.

Even this far inland, just above the reservoir, the river is impressive: several hundred metres wide and fast-flowing, thick with brown sediment. This turns out to be the first sign that something has gone wrong.

"Before the dam was built, they modelled everything," says Fan Xiao, an engineering geologist with the Sichuan Bureau of Geological Exploration and Exploitation of Mineral Resources. The model predicted that the water would slow down as it entered the top of the reservoir, near Chongqing, and drop most of its silt there, he says. But the flow through the reservoir is faster than predicted, so more silt is being carried further



Marvel or menace? Thirteen cities were razed to build Three Gorges, but without it CO₂ levels would be rising even faster

downstream towards the dam wall, and building up throughout the reservoir.

"According to a 2012 report, the dam is now retaining as much as 90 per cent," Fan says. In some parts of the reservoir, silt is building up to a depth of 60 metres – nearly two-thirds the maximum depth of the reservoir itself. The dam continues to accumulate silt at the rate of around 200 million cubic metres a year.

As a result, says Fan, one of two navigation channels that pass either side of an island in the reservoir has been completely blocked, forcing ship traffic in both directions to follow a single channel. Worse still, silt is building up at the dam wall. A lot of it has to be cleared by dredgers to make sure it doesn't interfere with the turbines that generate around 2 per cent of

China's electricity and the massive locks that allow ships to travel through.

The only way to slow the process is to build more dams upstream to trap the silt. Many were already being planned. If they are all built, the Yangtze will become a series of dams instead of a river. But this, as I found out later, won't help areas downstream of Three Gorges that are suffering from lack of sediment.

"13 cities, 140 towns and 1350 villages were drowned. About 1.3 million people had to move"

From Chongqing I have to catch a hot and sweaty bus through the mountainous folds of Sichuan province to the city of Fengjie, about two-thirds of the way down the reservoir, from where I can get a ferry to the dam wall. At least, this is the latest version of Fengjie. The original, as traders in a market delighted in telling me with drowning gestures, is now deep underwater.

The reincarnated city of Fengjie is as much of a marvel as the dam itself. It had to be rebuilt in its entirety at the top of a mountain to escape the rising waters of the reservoir. Every apartment complex, office block, school, hospital, road and shopping centre has been built from scratch, perched on slopes held back by massive concrete retaining walls. ➤

"The water started triggering quakes... I am predicting much bigger quakes"

What looked on the map like a 500-metre walk from my hotel to the ferry terminal turned out to be a labyrinthine schlep through skywalks, stairs and winding roads.

Fengjie is just one of 13 cities, 140 towns and 1350 villages drowned by the rising waters of the Three Gorges dam. Around 1.3 million people had to be moved. This new city at least seems to be thriving. In the evening the squares are filled with troupes of formation-dancing grannies, and the tables of crowded eateries spill into the street. At a restaurant where dozens of residents came to gawk at the only foreigner in town, one woman told me she and her husband had moved to Fengjie from Chengdu in 2008. "We love it here."

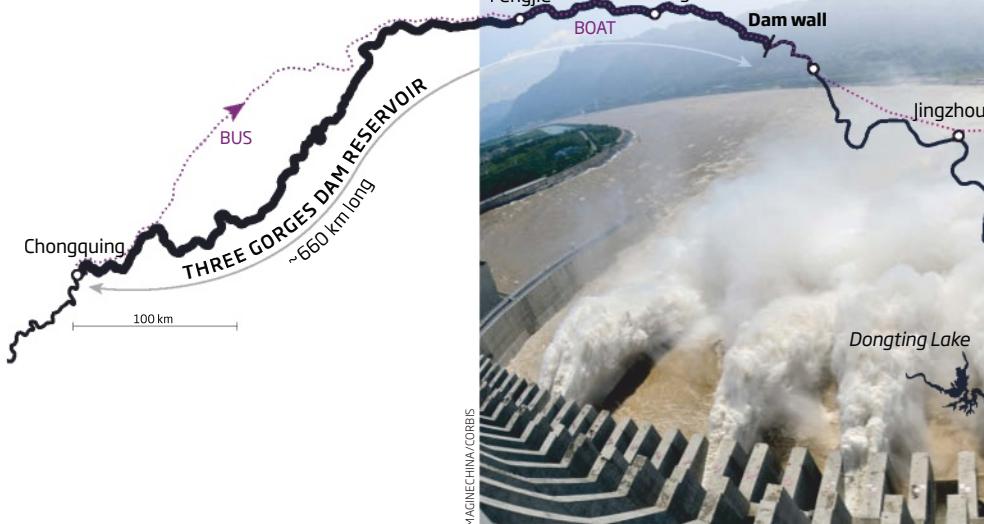
Further downstream lies the city of Badong. It was struck by a 5.1 magnitude quake in December last year, causing minor damage. It has long been known that the filling of a dam can trigger earthquakes, so the swarm of small quakes that have occurred around the Three Gorges over the last 10 years was expected. The seasonal raising and lowering of the reservoir may continue to trigger seismic activity.

Badong, however, is unlucky enough to lie on top of two fault lines. Fan thinks the pressure of the reservoir is forcing water into these fault lines, where it acts as a lubricant. "The water started triggering quakes at small fault lines about two kilometres down," says Fan. "Now it's reached 10 kilometres down, and this is where the more serious fault lines occur. I am predicting much bigger quakes in the near future." Some other geologists, however, say the Badong quake was not linked with the dam, and do not expect any future quakes to be much larger.

The filling of the reservoir has also destabilised some of the steep slopes lining the dam. Landslides are common, blocking roads and threatening villages. In September, a landslide destroyed the Lifengyuan Hydropower Station on one of the tributaries that feed the reservoir.

As the ferry from Fengjie skims over the calm surface of the reservoir, through the spectacular gorges after which the dam is named, gashes of bare earth can be seen marking the sites of recent landslides. Our boat glides over a part of the river once so treacherous that a Chinese poet described it as "a thousand seas poured into a cup". Now the waters are easily navigable.

Well, except for the fact that the boat has to push its way through a thick sheet of discarded plastic bottles, bags, algae and industrial crud that coat the surface of the reservoir; another side effect of the Three



Gorges dam. Pollution that used to be flushed downriver and out to sea is now trapped and backing up in the Yangtze's numerous tributaries. It covers a massive area despite 3000 tonnes being collected every day. Indifferent to the problem, a young man on the bank has cast a fishing line in the water. I make a mental note not to eat fish for the rest of the trip.

Eventually we reach the dam wall itself. Alongside the dam, there is a set of five staircase locks that lift freighters from the river below, a height of over 90 metres. Our guide tells us it takes 4 hours to negotiate them all. There is a parallel set of locks for ships going in the opposite direction.

There is no talk here of the environmental problems, only the benefits. And they are huge. Even critics concede that the Three Gorges dam is providing around 2 per cent of China's electricity – energy that would otherwise be produced mainly by dirty coal-fired power stations. To ensure an adequate winter supply of water for the dam's 32 turbines ("Each weighs the same as the Eiffel tower," says the fascinating-fact guide), the reservoir is filled to capacity every September.

Floodplain dries up

What the guide does not say is that this reduces the flow downstream, bringing forward the start of the Yangtze's natural low-water period. The result is that the Yangtze's once bountiful floodplain is now drying up. "China's two largest freshwater lakes – Poyang and Dongting – now find themselves higher than the river," says Patricia Adams of Probe



Turbocharged: the dam's massive turbines generate nearly 2 per cent of China's electricity

International, a Canadian environmental foundation that has written a number of critical reports about the Three Gorges dam. "The effect of that is that their water is flowing into the river and essentially draining these very important flood plains."

The lower water levels, combined with slower flow, pollution and restricted movement, have caused the Yangtze's fish population to crash. No one knows that better than the fisherman I met at Wuhan, waiting patiently for a catch in a dilapidated cabin on the riverbank. His net had been lowered into the water with a huge bamboo hoist, one of many on the bank. He was the only one trying his luck that hot afternoon. I asked what the fishing was like. "The fish are too small," he grumbled. "Way smaller than before."

He emerged from his little cabin and pulled



But more recently, erosion began to dominate.

The dam has made things even worse by nearly halving the amount of silt entering the delta, leading to a threefold jump in the erosion rate. This could become a major problem for a city that's just 1 metre above sea level on average and facing a sea level rise of perhaps 2 metres over the next century.

In the nearer term, the dam is allowing more seawater than ever to intrude into the Yangtze estuary by prolonging periods of low river flow. "From January to February there was always salinisation, even before the Three Gorges dam," says Fan Xiao. "But since the dam was built, the salinisation has begun much earlier, in September, and it's stronger than before. It's affecting the drinking water."

In 2011 and 2013, the Shanghai Water Authority reported "salt tides" affecting drinking water. And in February this year the salt intrusion was the worst yet. All of these were drought years, but the Three Gorges dam is a contributing factor.

The problems don't even stop at the river mouth. According to one study, the reduced flow is greatly decreasing the productivity of fisheries in the South China Sea.

Elsewhere in the world, many dam projects are acknowledged to have generated fewer benefits and greater drawbacks than anticipated. In China, the previous

on a rope, hoisting the net out of the water. Empty. He lowered it again, retired to his chair and waited. Twice more he hauled out an empty net before, on the third try, we saw a couple of little silver fish flopping around. "They're small! Way too small."

From Wuhan I travelled to my final destination, Shanghai. China's largest city is built on the river delta, on the billions of tonnes of sediment deposited by the Yangtze over the millennia. The main city is built around a small tributary of the Yangtze, so to see the river itself I had to take a suburban train and then walk. When I reach the Yangtze it is obscured by a high barrier designed to protect the headland against erosion.

Like all deltas, the mouth of the Yangtze is a tug of war between deposition and erosion. Between 1050 and 1990, according to a 2003 study, deposition won. During these 900 years the Nanhui foreland, which marks the south bank of the estuary, grew nearly 13 kilometres.

"Silt is building up much faster than predicted. One channel is already blocked"

government openly admitted that there were serious issues. "While the Three Gorges project has brought great and comprehensive benefits," said a statement by China's ruling State Council three years ago, "there are problems that must be urgently resolved in the resettlement and wealth-making of immigrants, environmental protection and geological disaster prevention." It suspended or scrapped other controversial dam projects.

Since 2011, there has been a change of leadership in China. Scientists who were once critical of the Three Gorges dam are now reluctant to talk publicly. One of them told me he had been warned not to speak out.

"There are more controls on the media because of the new government – it's a lot stricter," said Fan, one of the few still willing to talk on the record. "You have to be careful about what you say and about what you write." He was speaking freely to *New Scientist*, he said, because the government was more concerned about what was written in Chinese publications than overseas ones.

More dams to come

The change of government in 2012 has also led to a reinvigoration of hydropower. Many dam projects scrapped by the previous regime have now been reinstated. The official line is that there may be problems, but they can be addressed, and the benefits outweigh them.

"The Three Gorges project is doing more good than harm," Zhengshou Ren, deputy secretary general of the China Society for Hydropower Engineering, told the Xinhua news agency earlier this year. By June 2014, he says, the Three Gorges power station had saved the equivalent of 568 million tonnes of carbon dioxide.

This does not take into account the emissions associated with building the dam and moving cities, or the methane released from dam reservoirs. Still, over their life cycle dams produce far less CO₂ and other pollutants per gigawatt of electricity than coal-fired power stations. Without the Three Gorges dam, I might not have been able to see even half way across the wall.

As I left the river behind me I couldn't help feeling a tinge of guilt. We all benefit from the Three Gorges dam, after all, even though we live nowhere near it, because CO₂ emissions would be rising even faster without it. It is the people living along the Yangtze, who have and will continue to pay a heavy price. ■

Peter Hadfield is a freelance writer based in Sydney

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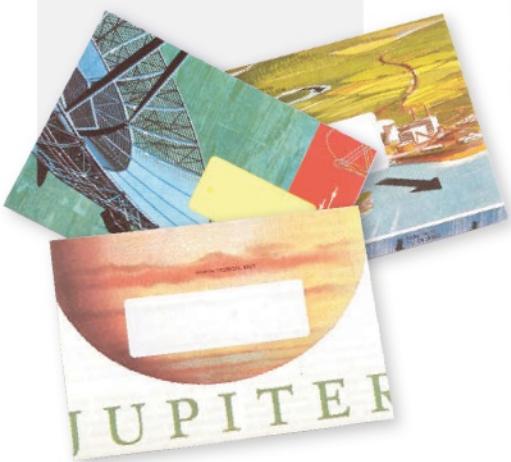
Give an ear to women in science, and you too can sport the piercing intelligence of Dorothy Hodgkin (pictured), Barbara McClintock or Marie Curie



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Cracking reads

Treat your friends and family to a science page-turner this Christmas

1 Does Santa Exist? A philosophical investigation by Eric Kaplan, Dutton/Penguin Books USA, £20

Its seriousness is clear from the title, so dive right in for some festive fun. Eric Kaplan, a writer and producer on hit TV series *The Big Bang Theory*, explores the intersection between logic and faith, and asks such questions as: if we are all going to die, what's the point of anything? What's a perfect moment? What can we say about God? Or Santa? Or *TBBT*'s Sheldon, come to that.

2 The Sense of Style: A thinking person's guide to writing in the 21st century by Steven Pinker, Allen Lane, £20/\$27.95

This seems an unusual outing for one of the world's top cognitive scientists and intellectuals. But it's not such a stretch really because Steven Pinker uses the latest research in his field to explain why writing well matters in an age of instant communication.

3 Soyuz Owners' Workshop Manual by David Baker, Haynes, £21.99

Though not quite fat enough to be a real repair manual, Haynes's latest foray into the history of heroic engineering is packed with detail and insight. The granddaddy of design classics, the Soviet Soyuz capsule has ferried people and packages into space for more than 50 years, and is still the world's go-to vehicle for leaving Earth.

4 The Knowledge: How to rebuild our world from scratch by Lewis Dartnell, Random House, £20

Do you lie awake at night wondering what would happen if we earthlings were devastated by an asteroid or a plague? Fear not, astrobiologist Lewis

Darwin would have loved them: evolution bookends are £20 at sciemuseumshop.co.uk

Dartnell has written the ultimate survival guide. Inside we can learn, or rather relearn, how to grow food, make clothes, generate energy, develop medicines and, crucially, make beer.

5 Note-by-Note Cooking: The future of food by Hervé This, Columbia University Press, £16.95/\$24.95

Not a cookbook, but keen cooks (and anyone with half an eye on entering BBC's *Masterchef*) will devour the latest work by molecular gastronomist Hervé This. Why work with whole ingredients when the components of food can be recombined to make novel flavours, odours and textures? Delicious, and slightly terrifying.

6 The Owl Who Liked Sitting on Caesar: Life with an enchanting tawny owl by Martin Windrow, Corgi, £9.99

New in paperback, Martin Windrow's account of his 15-year relationship

with a tawny owl isn't a typical natural history - Mumble, the razor-clawed "cat with wings", was born and reared entirely in captivity. However, his memoir, while charming, also does real work, perfectly capturing the sheer oddness of our relationships with animals.

"How long would someone stay alive if their DNA vanished? Randall Munroe has the answer"

7 What If: Serious scientific answers to absurd hypothetical questions by Randall Munroe, John Murray, £14.99

Randall Munroe is the creator of the cult smash hit webcomic *xkcd* and has an asteroid named after him (4942 Munroe - big enough to cause mass extinction if it hit Earth). His new book answers a range of questions, including old favourites such as: what would happen if everyone on Earth

stood as close together as they could, jumped up and then landed at the same time? Others are more bizarre, such as: how long would someone last if their DNA suddenly vanished?

8 The Silent History by Eli Horowitz, Kevin Moffett and Matthew Derby, Jonathan Cape, £9.99

A generation of children is born without the power of speech. This is the premise behind one of the year's more unlikely literary experiments. The three authors - all contributors to the literary magazine *McSweeney's* - riffed on each other's work via an app to come up with this chilling and intelligent thriller about words and intelligence, youth and politics.

9 Kitten Clone: Inside Alcatel-Lucent by Douglas Coupland, Visual Editions, £25/\$40

The moment something useful gets built, you can bet some smart-alec novelist will take the mickey out of it. Twenty years ago, Coupland's cult classic *Microserfs* served the nascent IT industry up on a platter. Kudos to telecommunications giant Alcatel-Lucent, then, for letting him play among its server farms.

10 This Changes Everything by Naomi Klein, Allen Lane, £20/\$18.72

Folk who like books that wear their polemic on their sleeve (or rather, dust jacket) will love this book. Journalist Naomi Klein (of *No Logo* and *The Shock Doctrine* fame) doesn't pull any punches as she examines climate change, its science, the deniers and all those with vested interests. ■



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The Biomedical Informatics Research Training (BIRT) Program is a consortium of leading informatics laboratories at Harvard. It is supported by a grant from the National Library of Medicine, National Institutes of Health. For United States citizens and permanent residents, this post-doctoral fellowship provides stipend, tuition, and travel funds. Selected fellows are provided with many opportunities for training, research, interaction, and collaboration. All fellows also pursue the two-year Harvard Medical School Biomedical Informatics MMSc.

The MMSc is a post-doctoral degree program that consists of course work and mentored research. Fellows in our program choose from one of four possible tracks: Bioinformatics; Clinical Informatics; Imaging Informatics; and Population Health Informatics.

To learn more, visit: informaticstraining.hms.harvard.edu/

In addition to the BIRT program, the Center for Biomedical Informatics (CMBI) offers a number of other training and research opportunities.

For more information about our programs, contact Aimee Doe, Program Coordinator, at Aimee_Doe@hms.harvard.edu

Harvard University Cambridge, Massachusetts



Tenure-Track Assistant Professorship in Chemistry and Chemical Biology

Candidates are invited to apply for an open-field tenure-track assistant professorship in the Department of Chemistry and Chemical Biology at Harvard University. The appointment is expected to begin on July 1, 2015. The tenure-track professor will be responsible for teaching at the undergraduate and graduate levels. We are seeking candidates who have an outstanding research record and a strong commitment to undergraduate and graduate teaching. Doctorate required by expected start date. Candidates should arrange to have three letters of recommendation sent independently and provide a curriculum vitae, statement of teaching philosophy, list of publications, and outline of their future research plans.

All applications and supporting materials must be submitted via the ARLeS portal (<http://academicpositions.harvard.edu/postings/5829>) no later than December 15, 2014.

Harvard is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law.



A culture of outstanding results leads to an award-winning culture. Make the connection.

At AstraZeneca, we're proud to have gained a host of awards for our progressive and diverse working practices. But we never rest on our laurels. Each award we receive pushes us further, and strengthens the connections between fellow employees, patients, stakeholders and the communities we serve and value.

Here are some of the awards we have recently been honoured with:

AstraZeneca was named a top 10 company for Executive Women in 2014's National Association for Female Executives Awards.

Committed to increasing the number of women in senior roles, we set exacting goals. Two years ago, AstraZeneca announced that by 2015 we wanted women to represent 38% of our talent pool, and 43% of senior managers worldwide. These numbers have already reached 34% and 40%.

The Human Rights Campaign Foundation handed AstraZeneca the Best Place to Work for LGBT Equality 2014 Award.

We received a high score on the 2014 Corporate Equality Index (CEI), a national benchmarking survey on corporate policies and practices relating to lesbian, gay, bisexual, and transgender (LGBT) workplace equality.

AstraZeneca is a global, top 100 InDemand Employer, as recognized by LinkedIn in 2013.

As one of the world's most attractive employers, we appear on LinkedIn's Global 100 InDemand Employers list - based on billions of interactions between LinkedIn's 238 million members.

We were the winner of the Opportunity Now Global Award in 2013.

This award is given for pursuing a positive gender initiative across at least three countries. It was awarded to AstraZeneca for our 'Asia for Global' talent development programme.

Other awards we have been delighted to receive include:

- Hispanic Choice Award - Alianza Award for Company of the Year (2014).
- Working Mother Magazine's 100 Best Companies for Working Mothers (2014).
- Three AstraZeneca employees were named in Diversity MBA Magazine's list of top 100 under 50 diverse emerging leaders (2014).
- Philadelphia Business Journal's Healthiest Employers Awards (2014).
- NBGH Best Employers for Healthy Lifestyles® Awards (2014).
- Washington Business Journal's 2014 Healthiest Employer Award.

If you share our passion for excellence, find out more about our career opportunities at www.astrazenecacareers.com



SILENCE and gold. Are they related? We have previously mused on the copyright status of the John Cage composition 4'33" - four-and-a-half minutes during which not a single note is played (1 November). Delightfully, we discover a small but perfectly formed study of the issue of copyright and silence in the form of an essay at bit.ly/SilenceMA.

It reveals that when musician Mike Batt put a track called *A One Minute Silence* on an album, the composers appeared as "Batt/Cage". In the UK, PRS for Music collects royalties when music is played in public - on the radio, for example - and distributes the money to composers and to owners of the so-called "mechanical right" in recordings. It faithfully noted the writing credit and made an entry on John Cage's ledger in respect of... er, what? Who is to say whether any and every silence on the radio constitutes use of the track or not?

Batt, however, had officially

registered "Clint Cage" as a pseudonym. So this particular silence was co-authored by two instances of the same person.

Feedback envies the colleague who has a copy of the printed score, which instructs the performers not to touch their instruments but permits any ambient sound.

At bit.ly/BBC433 you can hear licensed excerpts of performances, including one by Cage Against the Machine - an all-star attempt to keep a talent-show product out of the top spot in the 2010 festive season charts.

Our favourite version, though, remains the one performed at the 2010 Boring Conference in London, which observed the letter if not the spirit of the score by taking ambient sound to be the singing of one Martin White, to the vigorous accompaniment

of the ukulele, about things that can be accomplished in 4 minutes and 33 seconds.

ALMOST certainly not violating any rights of John Cage is the two-CD set *Kenotaphion*, to which the above-mentioned colleague with an interest in silence alerts us. It was released in 2001 on 11 November - Armistice Day - by Jonty Semper, who told the *Guardian* newspaper that he didn't think listeners would be bored by his compilation of every surviving recording of two-minute silences observed at the Cenotaph in London. "All the silences are quite distinctive," he said. "What is remarkable is how different they are."

FEEDBACK is now intrigued by the implications for information theory. How little data can a recording contain and still count as a recording?

AFTER reporting on premonitions of the internet (15 November), we came across a page from a 1964 issue of *Tape Recording* magazine, sent in by Chris Drewe. It reports predictions by Marvin Camras, "widely seen as the father of magnetic tape recording". By 2013, Camras predicted, "there will be no question of going out to buy a disc - or even a tape record". We would all own a recording apparatus "no larger than a box of playing cards, with no mechanically moving parts".

Anyone wanting music would "ring up and it will be transmitted over a direct line" to that box. Furthermore, we "may no longer need currency" since we would all have a "magnetic credit card". Well done!

One prediction may have been a tad too trusting of rationality in technological advancement. In electronic commerce, "the appropriate tax will automatically be deducted", Camras predicted. Feedback suspects he did not intend "appropriate" to include derisory rates of tax on the profits of internet corporations nominally based in Luxembourg.

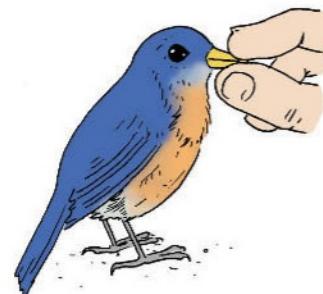
TALKING of prediction, we recall mentioning powdered alcohol as "one of those stories that comes

around once every decade or so, much as 'videophones' used to" (5 July). We found patents for powdered alcohol filed at 10-year intervals from 1964 (2 August).

Now, in the ever-entertaining Modern Mechanix blog, we find a plug for a videophone from the Toshiba corporation in July 1964 (bit.ly/ToshPhone). A metre long, it was intended to sell for \$250 - nearly \$2000 at today's prices. "It can be used on ordinary telephone lines," the blurb says: "Push a button and within five seconds the picture appears." Do you have more recent sightings?

FINALLY, reviewing the short links we had created reminded us to check the status of Twitter's application in the European Union for extended trademark protection of the word "Tweet" - see bit.ly/TweetPencils (26 July). Scrutiny of the application was completed on 28 October and it was published the following day - see bit.ly/TweetPencils2.

Skimming more than 750 contexts in which usage of the word would be



restricted, should the application be approved, we discover they include "cremation... night guards, copyright management, opening of security locks, organising and conducting religious meetings... [and] escorting in society (chaperoning)". Should any escorts, or others, wish to object, the deadline is 29 January 2015.

IN MEMORY

John Hoyland, editor of Feedback for many years, died last week. A comic and raconteur, John made innumerable contributions to *New Scientist* over more than 25 years, most famously the concept of "nominative determinism". He was a greatly loved member of the team. We will all miss him.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Boil foils

I reheated a mug of instant coffee in the microwave, but left it too long and it was boiling over when I took it out. I ran a little cold water into the mug to cool the coffee, and it boiled again. The tap water ran in gently, and large active bubbles appeared on top of the coffee. How could this happen?

■ Boiling depends on bubbles of water vapour being able to form within the liquid that is being heated. That process is helped by the presence of nucleation sites – for example, sharp points on surfaces, suspended particles and existing small bubbles – all of which help new bubbles to form and grow.

If the pressure inside a bubble is less than that of the atmosphere on the liquid's surface, the bubble collapses. It is the noise of collapsing bubbles that makes a kettle "sing" just before it comes to the boil. Once the liquid has reached its boiling point, the vapour pressure inside the bubbles is sufficient for them to persist and rise to the surface, carrying molecules of the liquid into the air.

This is where things get less straightforward. The pressure required to stop a bubble of vapour collapsing is actually slightly greater than that on the liquid's surface.

Perhaps surprisingly, the excess pressure is inversely related to the bubble's radius. This means that the smaller the bubble, the higher the pressure needed, and since

pressure rises with temperature, so the hotter the bubble needs to be to persist.

This helps to explain why a liquid can be heated well above boiling point without boiling, provided no bubbles or sharp edges exist inside. Such a liquid is said to be superheated.

Microwaves heat a cup of coffee unevenly. So even though the coffee was boiling over when taken out of the microwave, parts of it may remain superheated

"Microwaves heat a cup of coffee unevenly, and parts of it can be superheated even if no longer bubbling"

after the existing bubbles have escaped. Indeed the average temperature may stay above boiling point.

The cold water that is then added to the mug immediately warms and gives up small bubbles of air (air is less soluble in warm than in cold water). These bubbles bring the coffee to the boil once again, by allowing new bubbles to form within the superheated regions.

The coffee can now boil vigorously, which is potentially dangerous as spitting and foaming of the hot liquid may occur. This is why microwave ovens and microwaveable meals often carry warnings to let food stand for a minute or so after cooking before being moved or stirred.

*Alan Goodwin
Cheadle Hulme, Cheshire, UK*

■ The coffee was probably not actually boiling; rather, dissolved air was escaping.

Take a pan of tap water, put it on the stove and start heating it. Very quickly, tiny bubbles will form on the surface, even when the water is quite cool. You can test this (very cautiously) by dipping your finger in.

Tap water is often saturated with air. With most gases, the solubility in water decreases as the temperature rises, so the dissolved air escapes when the water is heated. The air bubbles expand as the temperature rises and they gradually detach from the pan's sides and rise quickly to the surface of the water, where they burst.

What has any of this to do with the coffee miraculously appearing to come back to the boil? When the cold tap water was added to the cup, the dissolved air in this water would come out of solution very quickly as it heated. As a result, these bubbles would rapidly expand and burst.

"It is difficult to distinguish between air bubbles forming and steam bubbles doing the same"

It is very difficult to visually distinguish between air bubbles forming, expanding and bursting and steam bubbles doing the same – but only the latter counts as boiling.

*Peter Borrow
Amersham, Buckinghamshire, UK*

The writers of answers that are published in the magazine will receive a cheque for £25 (or US\$ equivalent). Answers should be concise. We reserve the right to edit items for clarity and style. Please include a daytime telephone number and an email address if you have one. New Scientist retains total editorial control over the published content.

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This week's questions

RIGHT ON Q

I use predictive text on my cellphone. When I type the letter "q" I get suggestions, all of which start with "qu". When I then press "u", I get different suggestions. Why? I realise it's quite trivial, but I'd still love to know the answer.

*Andrew Barnett
Cheltenham, Victoria, Australia*

MIND LAGS BODY

I'm 77 and, like many people my age, tend to stoop rather than stand up straight. A few months ago I was standing by the kitchen door, talking idly. For some reason I turned and hit my head a stunning blow on the door frame. More recently I was looking over my wife's shoulder as she worked on her computer; I reached out my hand, pointing to something on the screen. As I pulled my hand back, my fingers got caught in a box on the table and I toppled it over on to the floor, spilling its contents. After a while I realised that both times I'd been stooping. In my mind's eye my head was clear of the door frame and my hand well above the table, but my stoop cancelled both. Is our body image slow to adjust to reality? If so why, and can it be fixed?

*Peter Laurie
Abbotsbury, Dorset, UK*

CLOUD COVER

How much data does the World Wide Web hold?

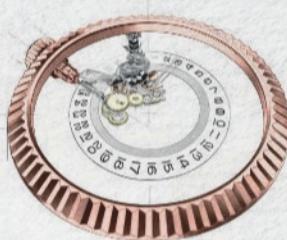
*Colin Singleton
Sheffield, UK*

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